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ABSTRACT

This guide provides information to enable coordinators to direct learning activities for students using an individualized study guide on operating a milling machine. The study material is designed for students enrolled in cooperative part-time training and employed, or desiring to be employed, as milling machine operators. Contents include a sample progress chart, suggested teaching procedures for the coordinators, answers to a unit test, a sheet with the study guide objective and specific objectives, eight information sheets, 11 assignment sheets, nine transparency masters, and an eight-part unit test (each part covers one information sheet). The information sheets cover these topics: terms and definitions, milling machine safety, introduction to milling, milling accessories, operation of the milling machine, milling calculations, basic hand and power tools, and metals and shapes. (YLB)

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TX831330

Individualized Study Guide

# GENERAL METAL TRADES

# MILLING MACHINE OPERATOR

## Coordinator's Guide

*Prepared by James W. Dean*

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MILLING MACHINE OPERATOR

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# FOREWORD

This individualized study guide has been developed for the student who is enrolled in Cooperative Part-time Training and who is employed or desires to be employed as a milling machine operator. The study material is designed to provide the student with general information for immediate reinforcement on the job and to develop an understanding of the job prior to employment.

Even though these study guides are individualized, the coordinator should closely supervise each student's studies. To allow the coordinator to better direct the learning activities, both coordinator guides and student manuals are available. A progress chart provided in each student manual will allow the coordinator to pinpoint the progress a student has made toward each objective in the sequence in which they are completed.

Appreciation is expressed to those whose expertise made possible the development of these study guides. The assistance of these instructors in the development process assures that the materials are current of use to vocational teachers in Texas. The following instructors provided valuable assistance in the developmental process:

| | | |
|---|---|---|
| Fred Aikin | Mt. Pleasant High School | Mt. Pleasant, TX |
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| Darrell Fletcher | Port Neches High School | Port Neches, TX |
| D. G. Gober | Monahans High School | Monahans, TX |
| James Loracano | Tyler High School | Tyler, TX |

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Bill Barnes, PhD., Director
Occupational Curriculum Laboratory

Progress Chart for

# MILLING MACHINE OPERATOR

Name _____

School _____

| | | Date Completed |
|---|---|---|
| INFORMATION SHEET 1 | TERMS AND DEFINITIONS | |
| ASSIGNMENT SHEET 1 | IDENTIFY MILLING TERMS | |
| Test | Part 1 | |
| **OBJECTIVE** | Match terms associated with milling operations to the correct definition. | |
| INFORMATION SHEET 2 | MILLING MACHINE SAFETY | |
| ASSIGNMENT SHEET 2 | MILLING MACHINE SAFETY | |
| Test | Part 2 | |
| **OBJECTIVE** | Point out the correct safety practices to follow when operating a milling machine. | |
| INFORMATION SHEET 3 | INTRODUCTION TO MILLING | |
| ASSIGNMENT SHEET 3 | MILLING MACHINES AND PARTS | |
| Test | Part 3 | |
| **OBJECTIVE** | Identify the types and parts of a milling machine. | |
| INFORMATION SHEET 4 | MILLING ACCESSORIES | |
| ASSIGNMENT SHEET 4 | WORK HOLDING DEVICES | |
| ASSIGNMENT SHEET 5 | MILL CUTTERS | |
| Test | Part 4 | |
| **OBJECTIVE** | Identify the cutters and accessories used on the milling machine. | |
| INFORMATION SHEET 5 | OPERATION OF THE MILLING MACHINE | |
| ASSIGNMENT SHEET 6 | OPERATION OF THE MILLING MACHINE | |
| Test | Part 5 | |
| **OBJECTIVE** | Identify the types of operations performed on the milling machine. | |

| | | Date Completed |
|---|---|---|
| INFORMATION SHEET 6 | MILLING CALCULATIONS | |
| ASSIGNMENT SHEET 7 | CUTTING SPEEDS | |
| ASSIGNMENT SHEET 8 | REVOLUTIONS PER MINUTE | |
| ASSIGNMENT SHEET 9 | FEED SETTINGS | |
| Test | Part 6 | |
| **OBJECTIVE** | Identify the basic tools used in the milling operations. | |
| INFORMATION SHEET 7 | BASIC HAND AND POWER TOOLS | |
| ASSIGNMENT SHEET 10 | BASIC HAND AND POWER TOOLS | |
| Test | Part 7 | |
| **OBJECTIVE** | Make simple calculations like cutting speeds, revolutions per minute and feed settings. | |
| INFORMATION SHEET 8 | METALS AND SHAPES | |
| ASSIGNMENT SHEET 11 | METAL AND SHAPES | |
| Test | Part 8 | |
| **OBJECTIVE** | Identify the job of metallurgist, list the major groups of metals, and recognize common shapes of metals. | |

This student has completed the indicated training under my supervision.

Teacher

# MILLING MACHINE OPERATOR

## SUGGESTED TEACHING PROCEDURES FOR THE COORDINATOR

I. Objective sheet

A. Discuss each objective with the student.

B. Explain the relationship of each objective to the student's training station.

C. Have the student complete the objectives in the most logical sequence for the training station.

(NOTE: A change of sequence is necessary only if a student changes jobs during the year or an employer requests training in a specific area.)

D. Add any objectives necessary for the training station.

II. Answers to assignment sheets

A. Some of the assignment sheets will vary according to training and should be graded individually.

B. Some assignment sheets will not have specifics but will depend on student participation.

III. Answers to unit test

A. Answers are based on total information covered in the unit.

B. For convenience of grading, make corresponding answer sheets for additional test parts added.

IV. Information and corresponding assignment sheets

A. INFORMATION SHEET 1--TERMS AND DEFINITIONS

1. Have the student review the information sheet and then discuss the terms and vocabulary associated with milling machines.

2. Use ASSIGNMENT SHEET 1--IDENTIFY MILLING TERMS to reinforce this area of information.

(NOTE: Have the student match the correct milling term to the correct definition for that term.)

3. Have the student's employer explain the milling terms associated with their work at the training station where assigned.

B. INFORMATION SHEET 2--MILLING MACHINE SAFETY

1. Have the student review the information sheet and then discuss and point out the importance of work safety.

2. Use ASSIGNMENT SHEET 2--MILLING MACHINE SAFETY to reinforce this area of instruction.

   (NOTE: Have the student discuss the causes of accidents at the training station where assigned.)

3. Have the student's employer explain the importance of good safety habits on the job and relate them to their operation.

C. INFORMATION SHEET 3--INTRODUCTION TO MILLING

1. Have the student review the information sheet and then discuss the following with the student:

   a. Operations of the milling machine

   b. Classifications of milling machines

   c. Types of Column and Knee milling machines (TM-1)

   d. Parts of the milling machine (TM-2, TM-3)

2. Use ASSIGNMENT SHEET 3--MILLING MACHINES AND PARTS to reinforce this area of information

3. Have the student's employer explain the following to the student:

   a. Different operations performed on the milling machine

   b. Classification of milling machine(s) used at the assigned training station

   c. Types of Column and Knee milling machine(s) used at the assigned training station

   d. The parts and their functions of the milling machine(s) used at the training station

D. INFORMATION SHEET 4--MILLING ACCESSORIES

1. Have the student review the information sheet and then discuss the following with the student:

   a. Working holding devices (TM-4, TM-5)

   b. Other accessories (TM-6)

   c. Mill cutters commonly used

2. Use the following assignment sheets to reinforce this area of information:

   a. ASSIGNMENT SHEET 4--WORK HOLDING DEVICES

      (NOTE: Have the student identify the work holding devices and write the correct name for each.)

b. ASSIGNMENT SHEET 5--MILL CUTTER

(NOTE: Have the student identify the mill cutters and write the correct name for each.)

3. Have the student's employer show the student the various types of milling accessories used at the assigned training station.

4. Have the student's employer demonstrate the use of the milling accessories used at the assigned training station.

5. Have the student make a list of milling accessories used by the student at the training station assigned.

E. INFORMATION SHEET 5--OPERATION OF THE MILLING MACHINE

1. Have the student review the information sheet and then discuss the following with the student:

a. Types of operations

b. Methods of milling

c. Things to consider when setting feed and cutting speeds

2. Use ASSIGNMENT SHEET 6--OPERATION OF THE MILLING MACHINE to reinforce this area of information.

3. Have the student's employer explain and demonstrate the types of operations performed on the milling machine(s) at the assigned training station.

F. INFORMATION SHEET 6--MILLING CALCULATION

1. Have the student review the information sheet and then discuss the following with the student:

a. Cutting speed

b. Revolutions per minute

c. Feed

d. Use of charts on TM-7 through TM-9

2. Use the following assignment sheets to reinforce this area of information:

a. ASSIGNMENT SHEET 7--CUTTING SPEEDS

b. ASSIGNMENT SHEET 8--REVOLUTIONS PER MINUTE

c. ASSIGNMENT SHEET 9--FEED SETTINGS

(NOTE: Have the student look up the information required to work the problems in one of the above assignment sheets. Charts and tables are provided on the TMs in the student's manual.)

3. Have the student's employer show the student how to set cutting speeds, RPMs, and feed settings on the milling machine(s) at the assigned training station.

G. INFORMATION SHEET 7--BASIC HAND AND POWER TOOLS

1. Have the student review the information sheet and then discuss the basic hand and power tools with the student.

2. Use ASSIGNMENT SHEET 10--BASIC HAND AND POWER TOOLS to reinforce this area of information.

(NOTE: Have the students identify and make a list of the hand and power tools used by the student at the assigned training station.)

3. Have the student's employer explain and demonstrate the proper and safe use of the hand and power tools used on the job.

V. Transparency masters

(NOTE: Transparencies are provided in the students' manuals as information sheets.)

A. TM-1--TYPES OF COLUMN AND KNEE MILLING MACHINES

B. TM-2--PARTS OF A HORIZONTAL MILLING MACHINE

C. TM-3--PARTS OF A VERTICAL MILLING MACHINE

D. TM-4--TYPES OF VISES

E. TM-5--A TYPICAL SCREW JACK, CLAMP AND BLOCK SET UP

F. TM-6--PARTS OF A DIVIDING HEAD

G. TM-7--RPM FOR HIGH SPEED STEEL CUTTERS

H. TM-8--CUTTING SPEEDS

I. TM-9--RECOMMENDED FEED IN INCHES PER TOOTH

VI. Unit test

A. The unit test is divided into seven parts.

(NOTE: Each part covers one information sheet.)

B. Various approaches may be used in testing:

1. Each part of the test may be given as the student reviews the information on each information sheet.

2. Give the entire test upon completion of all the information sheets in the unit.

3. Give one or more parts of the test as an additional assignment, or to reinforce areas the student did not understand.

C. Add test parts corresponding to any information area or sheets added to the unit.

VII. References

A. A Suggested Basic Course Outline for General Metal Trades Cluster. Occupational Curriculum Laboratory, East Texas State University, Commerce, TX 75428.

B. Ludwig, Oswald A. and William J. McCarthy. Metalwork Technology and Practice. McKnight and McKnight, Bloomington, IL 1969.

C. Wasiloff, Thomas. Machine Shop Skill Manual. American Technical Society, Chicago, IL 60637.

D. Walker, John R. Modern Metalworking. Goodheart-Wilcox, South Holland, IL (1976).

# MILLING MACHINE OPERATOR

## ANSWERS TO ASSIGNMENTS



### Assignment Sheet 1

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A. | 2 | G. | 15 | M. | 11 | | |
| B. | 14 | H. | 22 | N. | 6 | S. | 19 |
| C. | 5 | I. | 18 | O. | 10 | T. | 9 |
| D. | 12 | J. | 21 | P. | 17 | U. | 4 |
| E. | 23 | K. | 8 | Q. | 20 | V. | 7 |
| F. | 16 | L. | 13 | R. | 3 | W. | 1 |

### Assignment Sheet 2

| | | | |
|---|---|---|---|
| A. | True | F. | True |
| B. | False | G. | False |
| C. | False | H. | False |
| D. | True | I. | True |
| E. | False | J. | True |

### Assignment Sheet 3

A. 1. The type of milling machine.
   2. The kind of milling cutter used.
   3. The kind of accessories or attachments available for use with the milling machine.

B. 1. Fixed bed.
   2. Column and knee.

C. 1. Horizontal
   2. Vertical
   3. Combination horizontal and vertical

D. 1. Horizontal
   2. Vertical

E. 1. Overarm
   2. Arbor support
   3. Column
   4. Step blocks
   5. Vise
   6. T-slot bolt
   7. Strap blocks
   8. Rotary table

### Assignment Sheet 4

| | | | | | |
|---|---|---|---|---|---|
| 1. | T-slot clamp | 4. | Step blocks | 7. | Strap blocks |
| 2. | Screw jack | 5. | Vise | 8. | Rotary table |
| 3. | Dividing head | 6. | T-slot bolt | | |

Assignment Sheet 5

1. Angle mill cutter
2. Plain mill cutter
3. Key-seat cutter
4. Helical plain mill cutter
5. Side mill cutter
6. Metal slitting saw
7. Face-mill cutter
8. Boring bar
9. End-mill cutter
10. Flycutter
11. Formed tooth cutter
12. T-slot mill cutter

Assignment Sheet 6

A.
1. Straddle milling
2. Gear cutting
3. Facing
4. Form cutting
5. Slitting
6. T-slot cutting
7. Keyway cutting
8. Dovetail cutting
9. Angle cutting
10. Woodruff keyseat cutting
11. Boring

B.
1. Conventional milling (UP)
2. Climb milling (DOWN)

C.

| | | | |
|---|---|---|---|
| 1. | X | 5. | |
| 2. | | 6. | X |
| 3. | X | 7. | X |
| 4. | X | 8. | X |

Assignment Sheet 7

A. Refers to the distance, measured in feet, a point (tooth) on the cutter's circumference moves in one minute. Expressed as SFPM.

B. Answer should include four of the following:

1. Reduce speeds for hard materials, abrasive materials, high alloy materials, and deep cuts.
2. Increase speeds for soft materials, better finishes, light cuts and frail workpieces and setups.
3. Cutter type and material the cutter is made of.
4. Diameter of cutter.
5. Revolutions per minute.
6. Depth of cut.

C.

| | | | | | |
|---|---|---|---|---|---|
| 1. | 50-60 | 3. | 400 | 5. | 75-90 |
| 2. | 100-120 | 4. | 200-300 | 6. | 100-150 |

D. Approximately 48 SFPM's.

Assignment Sheet 8

A. Important for the speed setting of the spindle.

B. 1. Type of material being machined.
2. Cutter type and material the cutter is made of.
3. Type of cut, rough or finish.

C. 1. 306
2. 153
3. 76
4. 115
5. 46
6. 92

D. 1200 RPM's

Assignment Sheet 9

A. The rate work moves into the cutter.

B. Answer should include 4 of the following:
1. Width of cut.
2. Depth of cut.
3. Desired finish
4. Condition of machine and cutter.
5. Type of material being machined.
6. Cutter type and material the cutter is made of.

C. 1. 0.015
2. 0.012
3. 0.030
4. 0.003
5. 0.006
6. 0.017

D. 128

Assignment Sheet 10

A. 1. l
2. f
3. j
4. g
5. a
6. p
7. o
8. b
9. d
10. q
11. c
12. n
13. e
14. i
15. k
16. m
17. h

B. 1. Abrasive cutoff saw
2. Power hacksaw
3. Portable disk grinder/sander
4. Bandsaw

Assignment Sheet 11

A. To develop metals with special properties that perform a specific job and do it as economically as possible.

B. 1. Ferrous
2. Nonferrous
3. Alloys

C. 1. Steel rolled to desired shape and size while "red hot." Hot-rolled steel is identified by the bluish-black oxide that forms during and after the rolling process.

2. Hot-rolled steel shapes that are pickled or treated by running them through a dilute acid to remove the oxide coating. The metal is then rolled cold to the finished shape and size. Cold-rolled steel can be identified by its bright, shiney, silvery and oxide-free surface.

D.

| | | | | | |
|---|---|---|---|---|---|
| 1. | channel | 5. | round | 9. | H-beam |
| 2. | sheet | 6. | hexagon | 10. | octagon |
| 3. | plate | 7. | angle | 11. | square |
| 4. | I-beam | 8. | flats | 12. | strips |

# MILLING MACHINE OPERATOR

## ANSWERS TO TEST

### Part 1

| | | |
|---|---|---|
| a. 2 | f. 4 | k. 15 |
| b. 11 | g. 8 | l. 13 |
| c. 6 | h. 5 | m. 1 |
| d. 7 | i. 14 | n. 12 |
| e. 9 | j. 10 | o. 3 |

### Part 2

| | |
|---|---|
| a. False | f. True |
| b. True | g. False |
| c. False | h. False |
| d. True | i. False |
| e. False | j. True |

### Part 3

1. a. Fixed bed
   b. Column and knee

2. a. Overarm
   b. Arbor support
   c. Column
   d. Table
   e. Saddle
   f. Base
   g. Knee
   h. Motor assembly
   i. Speed selector
   j. Spindle

3. a. Horizontal
   b. Vertical

### Part 4

1. a. Dividing head
   b. T-slot bolt
   c. Rotary table
   d. Step blocks
   e. Strap blocks
   f. Vise
   g. T-slot clamps
   h. Screw jack

2. a. Plain mill cutter
   b. Side mill cutter
   c. Angle mill cutter
   d. Metal slitting saw
   e. Helical cutter
   f. Keyseat cutter
   g. Face mill cutter
   h. T-slot bolt
   i. End mill cutter
   j. Flycutter
   k. Boring bar
   l. Formed cutter

ANSWERS TO TEST

Part 5

1. a. Boring
   b. Gear cutting
   c. Form cutting
   d. T-slot cutting
   e. Keyway cutting
   f. Slitting
   g. Woodruff keyseat cutting
   h. Facing
   i. Dovetail cutting
   j. Straddle milling
   k. Angle cutting

2. a. Conventional milling (UP)
   b. Climb milling (DOWN)

3. a. X
   b.
   c. X
   d. X
   e.
   f. X
   g. X
   h. X

Part 6

1. a. Refers to the distance, measured in feet, a point (tooth) on the cutter's circumference moves in one minute.
   b. The rate work moves into the cutter.

2. 30
3. 400
4. 22

Part 7

1. a. 12 d. 7 g. 15 j. 17 l. 14 n. 9 p. 13
   b. 6 e. 1 h. 2 k. 3 m. 5 o. 11 q. 8
   c. 10 f. 16 i. 4

2. a. Abrasive cutoff saw
   b. Power hacksaw
   c. Portable disk grinder/sander
   d. Bandsaw

Part 8

1. Metallurgist

2. a. I-beam d. square g. octagon j. H-beam
   b. strips e. angle h. hexagon k. round
   c. flats f. plate i. sheet l. channel

3. a. ferrous metals
   b. alloy metals
   c. nonferrous metals

4. a. red hot
   b. bluish black
   c. hot-rolled steel shapes
   d. bright, shiny, silver-colored

# MILLING MACHINE OPERATOR

## STUDY GUIDE OBJECTIVES

After completion of the study guide, the student will be able to use the correct terminology and safety rules in performing the procedures and responsibilities required of a milling machine operator. The knowledge will be evidenced through demonstration and satisfactorily completing the study guide test.

## SPECIFIC OBJECTIVES

After completion of this unit, the student will be able to:

1. Match terms associated with milling operations to the correct definition.
2. Point out the correct safety practices to follow when operating a milling machine.
3. Identify the types and parts of a milling machine.
4. Identify the cutters and accessories used on the milling machine.
5. Identify the types of operations performed on the milling machine.
6. Identify the basic tools used in the milling operations.
7. Make simple calculations like cutting speeds, revolutions per minute and feed settings.
8. Identify the job of metallurgist, list the major groups of metals, and recognize common shapes of metals.

# MILLING MACHINE OPERATOR

## INFORMATION SHEET 1--TERMS AND DEFINITIONS

A. Mill--to remove metal with a rotating cutter on a milling machine.

B. Milling machine--a machine that removes metal from the work by using a rotary cutter.

C. Arbor--device used for holding and adapting milling cutters to the spindle of horizontal-type milling machines.

D. Axis--the centerline of a workpiece or stock.

E. Circumference--the distance around the outside curved edges of a round part.

F. Cutter--a multiple-toothed cutting tool usually made of high-speed steel mounted or inserted into the milling machine to be used to shape the workpiece.

G. Cutting fluid--a liquid used to cool and lubricate the cutting tool in order to improve the quality of the surface finish.

H. Adapter--a device which is used to mount cutters of various kinds on the milling machine spindle.

I. Horizontal--parallel to the ground.

J. Vertical--upright, or at a right angle to the ground.

K. Vise--the most widely used device for holding the workpiece during the milling process.

L. Holders--devices that are designed and used to hold straight shankend mills.

M. Cutting speed--the distance--measured in feet--that a point (tooth) on the circumference of the cutter moves in one minute. It is measured in surface feet per minute (SFPM).

N. SFPM--Surface feet per minute.

O. RPM--the number of revolutions per minute at which the machine's spindle must be set in order to turn the cutter properly.

P. Feed--the rate the workpiece moves into the cutter. It is measured in feed per tooth per revolution (FTR).

Q. FTR--feed per tooth per revolution.

R. Indexing--the process of dividing a round, or other other shape, workpiece into equal parts, using the dividing head.

S. Safety zone--the line or area that gives a safe distance from a cutter or machine.

T. Workpiece--the material or item being shaped or cut during the milling process.

U. Boring--a process used to make a straight hole to an accurate size. For most boring, the hole is drilled 1/16" to 1/8" undersize, and is then bored to the correct size.

V. Drilling--cutting a hole with a tool called a drill.

W. Keyway--a slot in a shaft to hold a key that fits into a slot of a pulley or gear to keep them from moving on the shaft.

# MILLING MACHINE OPERATOR

## ASSIGNMENT SHEET 1--IDENTIFY MILLING TERMS

Directions: Match the correct word or words from the right column to the correct definition at the left. Put the correct number in the space at the left.

| | | | |
|---|---|---|---|
| ____A. | To remove metal with a rotating cutter on a milling machine. | 1. | Keyway |
| ____B. | A machine that removes metal from the work by means of a rotary cutter. | 2. | Mill |
| ____C. | Device used for holding and adapting milling cutters to the spindle of horizontal type milling machines. | 3. | Indexing |
| ____D. | The centerline of a workpiece or stock. | 4. | Boring |
| ____E. | Outside distance around the curved edges of a round part. | 5. | Arbor |
| ____F. | A multiple-tooth cutting tool generally made of high-speed steel mounted or inserted into the milling machine for shaping the workpiece. | 6. | SFPM |
| ____G. | A liquid used to cool and lubricate the cutting tool to improve quality of the surface finish. | 7. | Drilling |
| ____H. | Device which is used to mount cutters of various kinds on the milling machine spindle. | 8. | Vise |
| ____I. | Parallel to the ground. | 9. | Workpiece |
| ____J. | Upright, or at a right angle to the ground. | 10. | RPM |
| ____K. | Most widely used device for holding the workpiece during the milling process. | 11. | Cutting speed |
| ____L. | Designed and used specifically for holding straight shank-end mills. | 12. | Axis |
| ____M. | The distance, measured in feet, a point (tooth) on the circumference of the cutter moves in one minute and expressed in surface feet per minute (SFPM). | 13. | Holders |
| ____N. | Surface feet per minute. | 14. | Milling machine |
| ____O. | Revolutions per minute the machine's spindle must be set to turn the cutter properly. | 15. | Cutting fluid |
| | | 16. | Cutter |
| | | 17. | Feed |
| | | 18. | Horizontal |
| | | 19. | Safety zone |
| | | 20. | FTR |
| | | 21. | Vertical |
| | | 22. | Adapter |
| | | 23. | Circumference |

ASSIGNMENT

____P. The rate the workpiece moves into the cutter and is given in feed per tooth per revolution (FTR).

____Q. Feed per tooth per revolution.

____R. The process of dividing a round or any other shaped workpiece into equal divisions, using the dividing head.

____S. The line or area that indicates a safe distance from a cutter or machine.

____T. Material or item being shaped or cut during the milling process.

____U. Performed to produce a very straight hole to accurate size. For ordinary boring, the hole is drilled from 1/16" to 1/8" undersize and then bored to the desired size.

____V. Cutting a hole with a tool called a drill.

____W. Slot in a shaft to hold a key that fits into a slot of a pulley or gear to prevent them from moving on the shaft.

1. Keyway
2. Mill
3. Indexing
4. Boring
5. Arbor
6. SFPM
7. Drilling
8. Vise
9. Workpiece
10. RPM
11. Cutting speed
12. Axis
13. Holders
14. Milling machine
15. Cutting fluid
16. Cutter
17. Feed
18. Horizontal
19. Safety zone
20. FTR
21. Vertical
22. Adapter
23. Circumference

MILLING MACHINE OPERATOR

INFORMATION SHEET 2--MILLING MACHINE SAFETY

Every day, hundreds of people suffer painful injuries because they have failed to use good judgment while working with or around machines. People generally have accidents because they are careless or ignore safety regulations regarding work habits and machines. Safety is not something you read or practice when you feel like it, but something that must be practiced daily. If one would observe safety on a daily basis and use a little common sense, many accidents could be avoided.

The main reason for the following safety practices is to alert you to some of the general safety rules one should follow while performing various milling machine operations.

A. Wear approved safety goggles or face shield at all times.

B. Clean and dry the table before mounting accessories.

C. Be sure that the accessories are securely fastened to the table.

D. Check the workpiece to see that it is securely mounted.

E. Select the proper cutter and make sure it is rotating in the proper direction.

(NOTE: Always use a sharp cutter.)

F. Be sure the arbor, cutter, or collars are clean before mounting them on the machine.

G. Use a rag to handle sharp cutters.

H. Keep fingers clear of the arbor hole when sliding the overarm in place.

(NOTE: Be sure the overarm is secured.)

I. Use correctly by fitting wrenches on the machine.

J. Tighten the arbor nut by hand, tightening with a wrench--NEVER use power for tightening.

K. Make adjustments with the machine STOPPED.

L. Always use the correct spindle speed, proper feed, and the correct depth of cut.

M. Use a soft-headed hammer to seat the workpiece in the vise.

N. Make sure that the table, work holding device, and workpiece will clear the arbor and arbor support during the cut.

O. Disengage the feed handwheels and handles when power feed is to be used.

P. Loosen the table, knee, and saddle clamps when making adjustments.

(NOTE: When adjustments have been made, tighten the clamps on the slides which should not move during the operation.)

Q. Make sure that unauthorized persons are not in the safety zone around the machine when the machine is started.

R. Stay clear of a revolving cutter and never reach over the cutter.

S. Stop the cutter to remove chips and then use a brush.

T. Check to be sure all power feed controls are stopped when the operation is completed.

U. Keep the floor area around the machine free of oil and chips.

V. Always clean the machine with a brush first and then a rag.

W. Always use hand feeding when moving the work up to the cutter--never use the power feed.

X. Always turn OFF the power to your machine if you must leave it, even for just a minute or two.

Y. Keep your hands away from the revolving cutter and machine parts at all times.

Z. Do not fool around while operating the mill. Keep your mind on your work and be ready for any emergency.

MILLING MACHINE OPERATOR

ASSIGNMENT SHEET 2--MILLING MACHINE SAFETY

Directions: Point out the correct safety rules by writing True or False in the blank for each of the following statements.

_____A. Wear approved safety goggles or face shield at all times.

_____B. Be sure that the accessories are loosely fastened to the table.

_____C. When necessary, tighten the arbor nut with a power wrench.

_____D. People generally have accidents because they are careless or ignore safety regulations regarding work habits and machines.

_____E. When moving the workpiece up to the cutter, always use the power feed to save time.

_____F. Always turn off the power to the milling machine if you must leave it, even for just a minute or two.

_____G. To save time at the end of the day, some cleaning can be done on the milling machine and around the cutter while the machine is in operation.

_____H. When seating the workpiece in the vise, use a large hard-headed ball peen hammer.

_____I. Make all adjustments with the machine stopped.

_____J. Make sure that unauthorized persons are not in the safety zone of the machine when the machine is started.

ASSIGNMENT

MILLING MACHINE OPERATOR

INFORMATION SHEET 3--INTRODUCTION TO MILLING

I. Operations of the milling machine

A. The milling machine is a machine tool which cuts metal with various types of cutters. The workpiece is mounted on the milling machine table and is fed against the revolving cutter.

B. Milling machines perform a wide variety of machining operations. The variety of milling operations which can be performed on a milling machine depends on the following:

1. The type of milling machine.

2. The kind of milling cutter used.

3. The kinds of accessories or attachments available for use with the milling machine.

C. Milling machine operations include the following:

1. Machine flat surfaces, including horizontal, vertical, and angular surfaces.

2. Machine many kinds of shoulders, grooves, T-slots, dovetails, and keyways.

3. Machine irregular or curved surfaces.

4. Perform basic hole machining operations, including drilling, reaming, countersinking, boring, and counterboring.

5. When equipped with a dividing head, machine equally spaced surfaces, grooves, or gear teeth on cylindrical shaped surfaces.

II. Classification of milling machines (TM-1)

A. Fixed bed--specially designed manufacturing milling machines which are used for mass production purposes. Not commonly found in schools or small business shops.

B. Column and knee--so named because the parts that provide movement to the work consist of a column that supports and guides the knee in vertical movement. Classified into the following types:

1. Horizontal type milling machines.

a. Plain

(1) Milling machine which the cutter turns on a horizontal axis

(NOTE: Can be changed to a vertical milling machine with a special attachment.)



INFORMATION

(2) Table with the three basic movements (vertical, cross-traverse, and long longitudinal)

b. Universal

(1) Similar to the plain milling machine, except the table will also swivel on the saddle of the machine.

(2) Swivel feature allows spiral gears, splines, and other helical work to be produced.

2. Vertical milling machine

a. Has a vertical axis which holds and turns the cutter.

b. Is used mainly for operations that call for the use of end mill or face mill cutters.

3. Combination horizontal and vertical machine

(NOTE: The machine is designed for both milling operations)

III. Parts of a milling machine (TMs 2 and 3)

A. Column--provides the support and alignment for the rest of the machine parts.

(NOTE: Ways are ground into the column to provide alignment.)

B. Base--provides the floor support for the column.

C. Knee--the large part in front of the machine which provides support for the saddle and bed, and houses most of the controls for the movement of the bed.

D. Saddle--sits on the ways of the knee, and moves the table to and away from the column.

(NOTE: Ways are ground into the saddle for the table to slip on.)

E. Table--travels to the right and left, and provides a working surface for the workpiece and attachments.

(NOTE: Tables on the universal horizontal milling machine will also swivel to about 45°.)

F. Overarm--provides support for the arbor, and also supports the motor assembly on vertical machines.

G. Feed selector--controls the feed rate of the table and workpiece in <u>inches per minute</u>.

(NOTE: The feed is usually separate from the speed of the spindle.)

H. Spindle--holds and turns the cutting tools in the milling machine.

(NOTE: The speed of the spindle is controlled by variable speed controls on the motor.)

I. Arbor--holds the cutting tool on a horizontal milling machine.

J. Motor assembly--provides the power source for turning the spindle.

(NOTE: Most motors have a speed range selector and a variable speed control to guide the spindle speed.)

MILLING MACHINE OPERATOR

ASSIGNMENT SHEET 3--MILLING MACHINES AND PARTS

A. A variety of milling operations can be performed on the milling machine and depend on three factors. List them below.

1. _____

2. _____

3. _____

B. List the two classifications of milling machine.

1. _____

2. _____

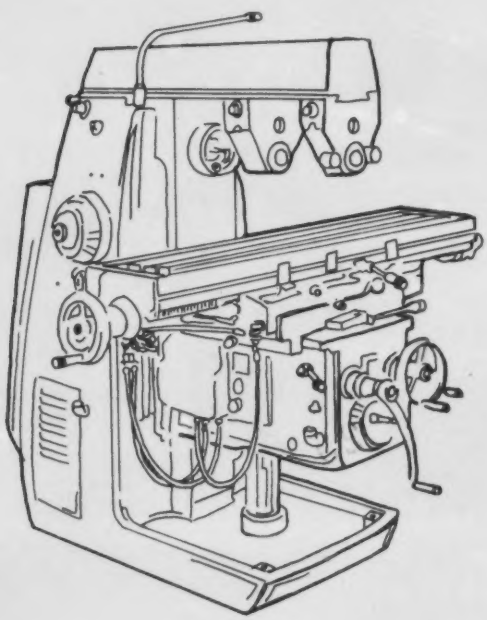
B. Name the three types of column and knee milling machines.

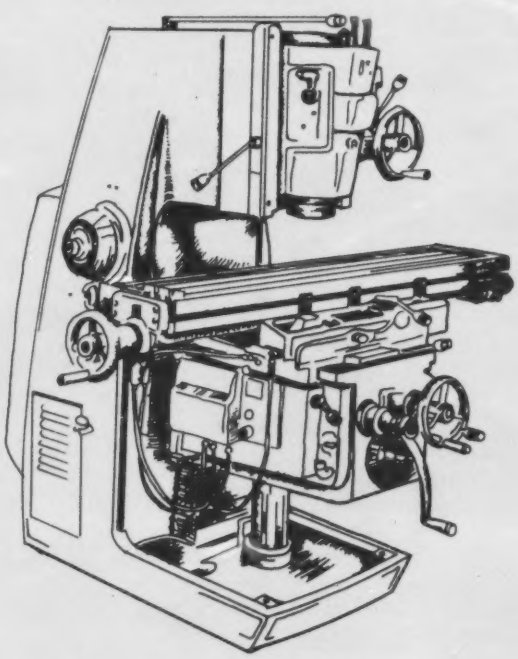
1. _____

2. _____

3. _____

C. Identify which of the milling machines is a horizontal or vertical type and write the name of each in the space provided.



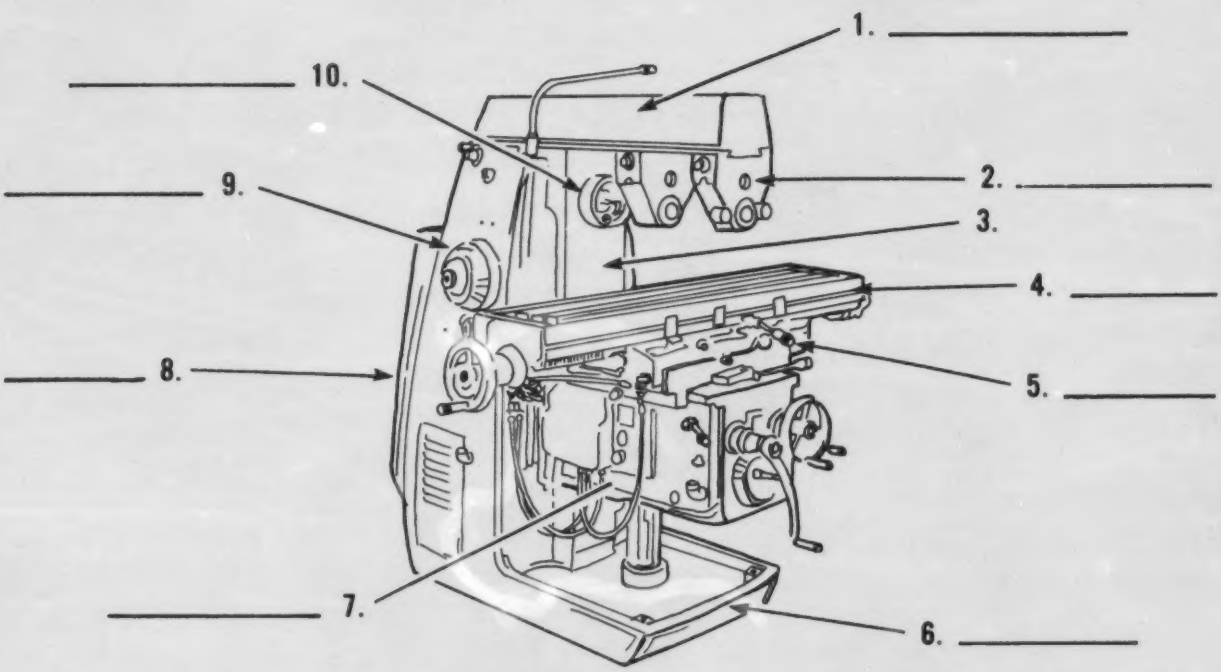


1. _____ 2. _____

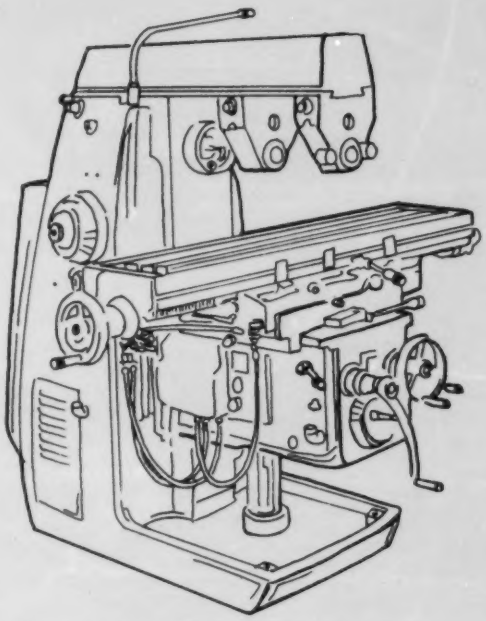
ASSIGNMENT

E. Identify the parts of a milling machine by labeling the illustration below the correct name from the table.

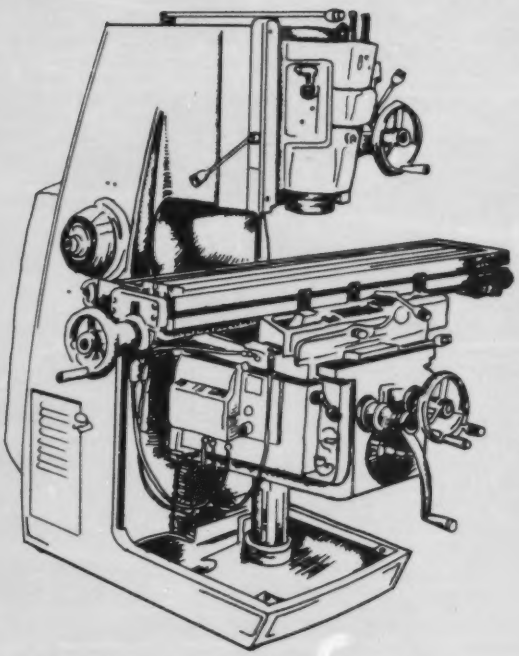
| | | |
|---|---|---|
| Column | Table | Arbor support |
| Base | Overarm | Motor assembly |
| Knee | Speed selector | |
| Saddle | Spindle | |



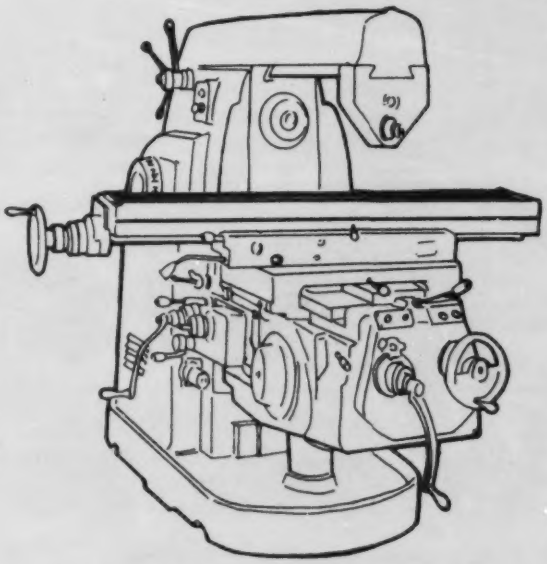
# TYPES OF MILLING MACHINES



HORIZONTAL MILLING MACHINE



VERTICAL MILLING MACHINE



UNIVERSAL MILLING MACHINE

TM-1

MILLING MACHINE OPERATOR

INFORMATION SHEET 4--MILLING ACCESSORIES

I. Work holding devices

A. Vises--clamped to the mill table to hold workpiece

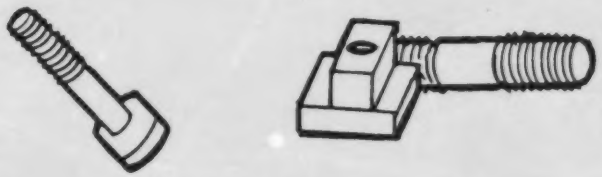
1. Plain

2. Swivel

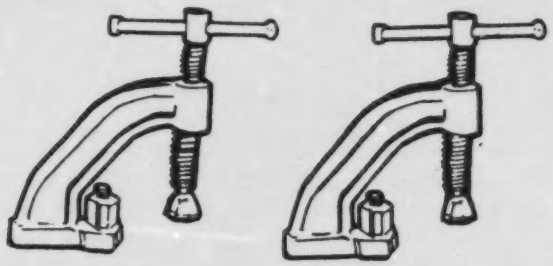
3. Universal

B. Clamping accessories--used to clamp work directly to the mill table.

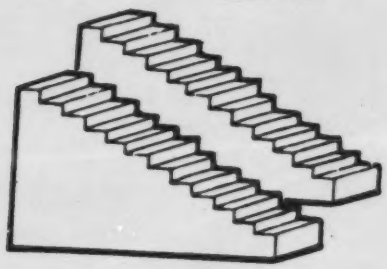
1. T-slot bolts



2. T-slot clamps



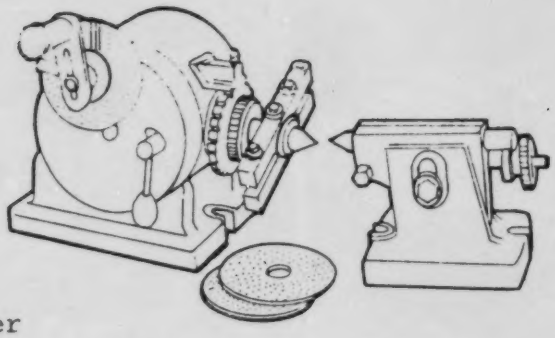
3. Step blocks



4. Strap blocks

5. Screw jack

C. Other accessories



1. Dividing head

   a. Use to turn a workpiece at a specified rate or in equal divisions during a milling operation.

   b. Turned by hand or power feed from the leadscrew through a gear train

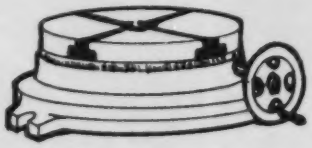
   c. Holds the workpiece in a horizontal or vertical position.

      (NOTE: A chuck is often used in place of the center when positioned vertically.)

   d. The spindle turns one turn for every 40 turns of the hand crank.

      (NOTE: This provides a gear ratio of 40:1.)

2. Rotary table

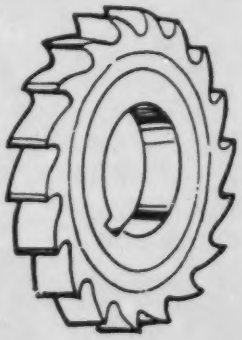


   a. Use to turn a workpiece for cutting a radius or performing milling operations at different locations at specified degree or location.

   b. The table is graduated in degrees and the hand wheel is graduated in minutes.

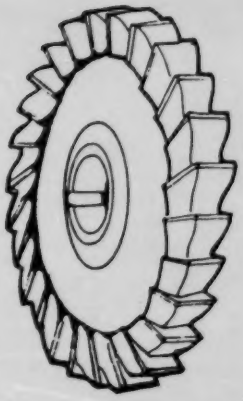
II. Millcutters

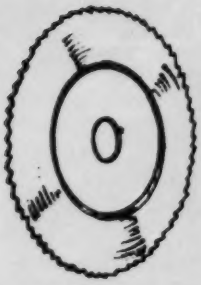
A. Plain mill cutter--a round cutting tool with teeth on the circumference.



B. Helical plain mill cutter--a cutting tool with a curved cutting edge that is used to take wide shallow cuts on soft metals.

C. Side mill cutter--a cutting tool with teeth on the side as well as the circumference.





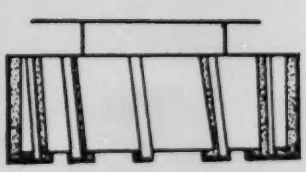
D. Metal slitting saw--a cutting tool used to cut narrow slots or for cutoff operations.

E. Angle mill cutter--a cutting tool used to cut angle cuts such as V-notches, V-grooves, dovetails, and reamer teeth.

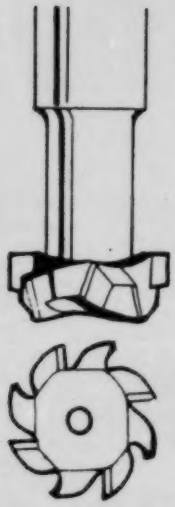
F. End-mill cutter--a cutting tool used to cut slots, keyways, flat surfaces, and shoulders.

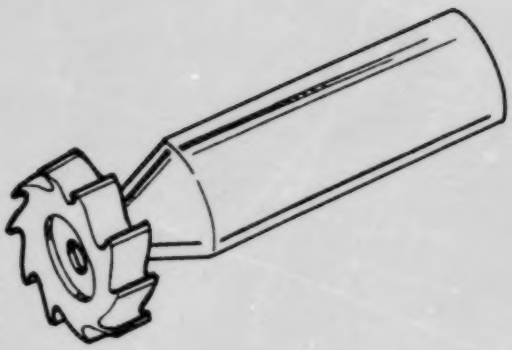
G. Face-mill cutter--a cutting tool used to mill large flat surfaces.

(NOTE: Face-mill cutters are over 6 inches in diameter and shell end-mill cutters are under 6 inches in diameter.)



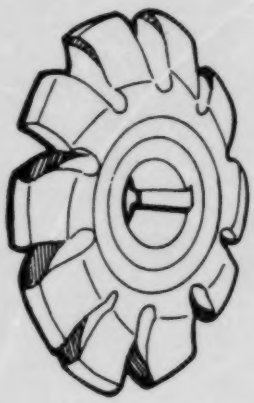
H. T-slot mill cutter--an end-mill cutter designed to cut T-shaped slots.





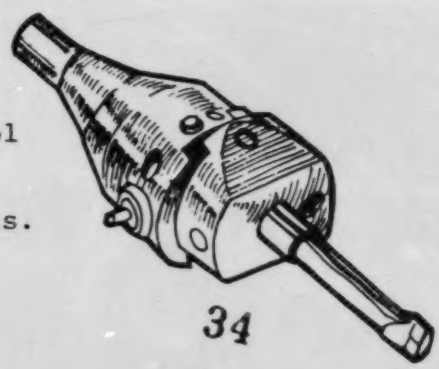
I. Key-seat cutter--an end mill cutter used to cut woodruff or half-moon key seats.

J. Formed-tooth cutter--a cutting tool used to cut irregular shapes such as a radius, gear tooth, convex, or concave surface.



K. Flycutter--a single point cutting tool used for facing operations.

L. Boring bar--a cutting tool to bore holes or cut internal surfaces such as cylinders on engine blocks.

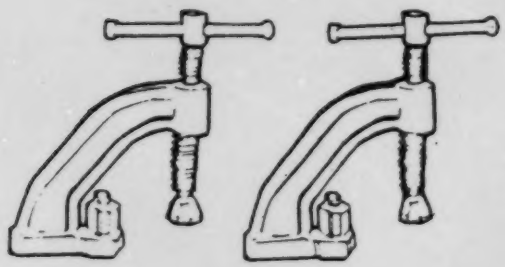


MILLING MACHINE OPERATOR

ASSIGNMENT SHEET 4--WORK HOLDING DEVICES

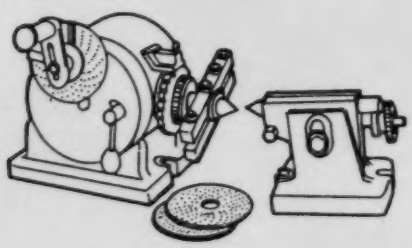
Directions: Identify the work holding devices used on the milling machine by writing each of the following names by the correct illustration.

Vise
T-slot bolt
T-slot clamp
Step blocks
Strap blocks
Screw jack
Dividing head
Rotary table

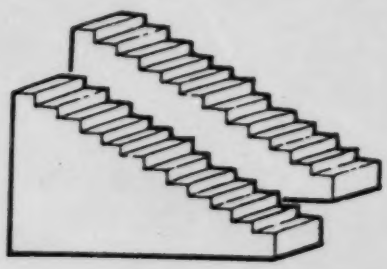


1. _____

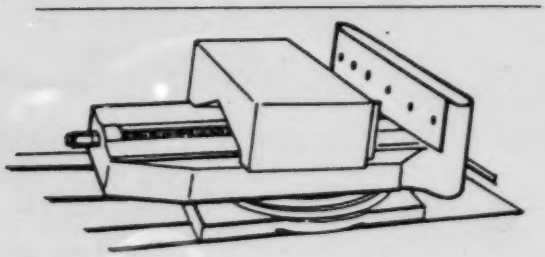
2. _____



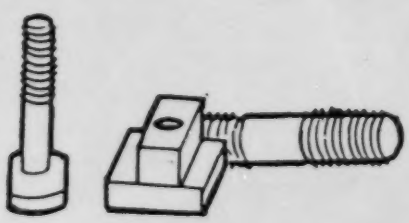
3. _____



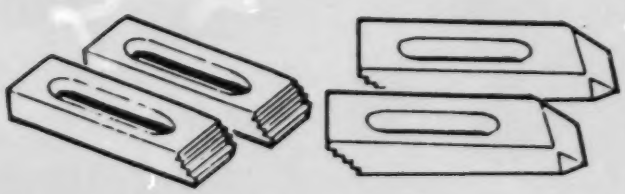
4. _____



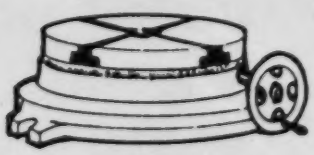
5. _____



6. _____



7. _____



8. _____

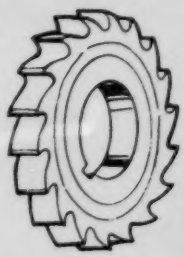
ASSIGNMENT

## ASSIGNMENT SHEET 5--MILL CUTTERS

Directions: Identify the types of milling cutters used on the milling machine by writing each name in the list below in the correct blank.

| | |
|---|---|
| Face-mill cutter | Plain mill cutter |
| Key-seat cutter | Side mill cutter |
| T-slot mill cutter | Metal slitting saw |
| End-mill cutter | Angle mill cutter |
| Helical plain mill cutter | Formed tooth cutter |
| Flycutter | Boring bar |

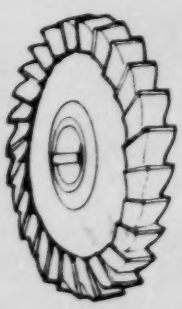
1. _____



2. _____

3. _____

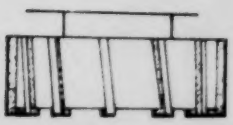
4. _____



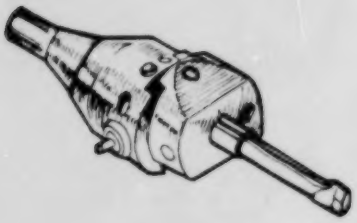
5. _____

6. _____

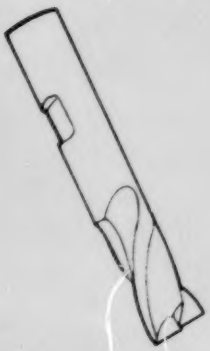
ASSIGNMENT



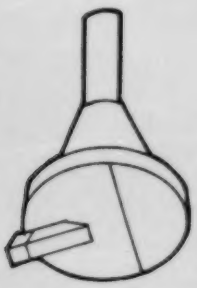
7. _____



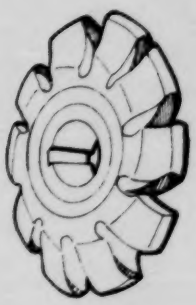
8. _____



9. _____



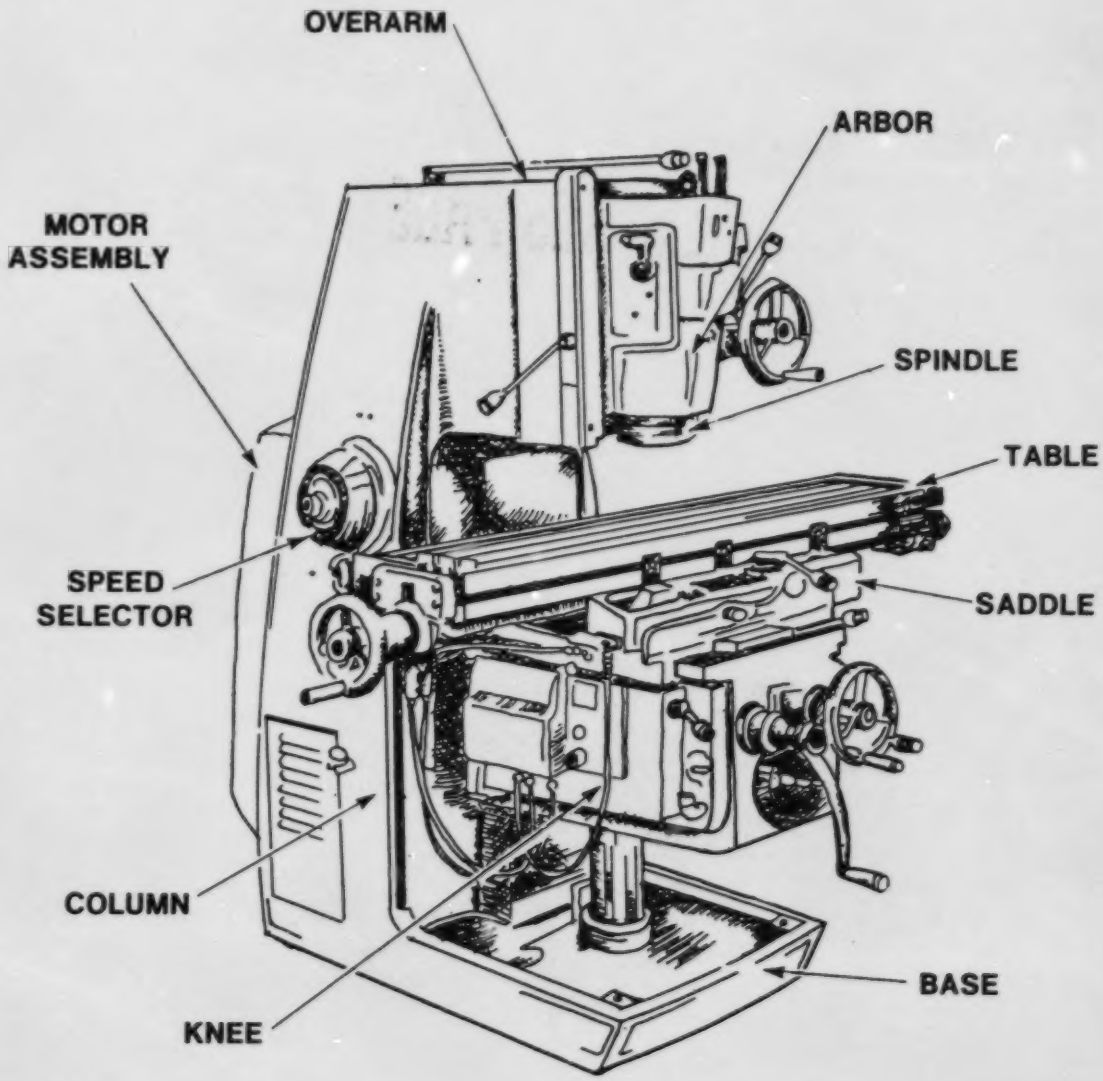
10. _____



11. _____

12. _____

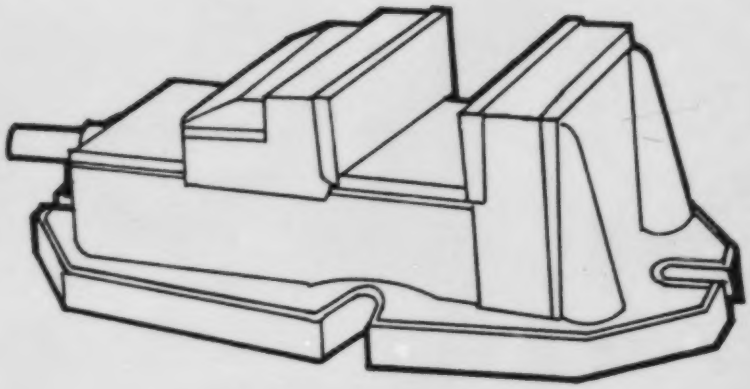
# PARTS OF A VERTICAL MILLING MACHINE

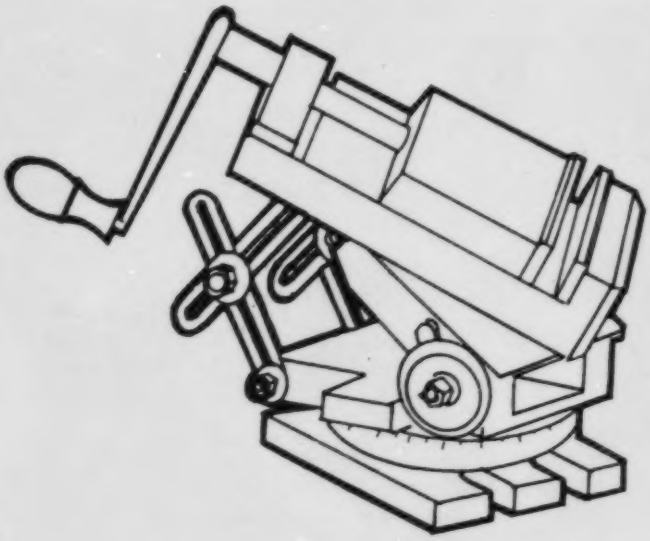



TM-3

# TYPES OF VISES

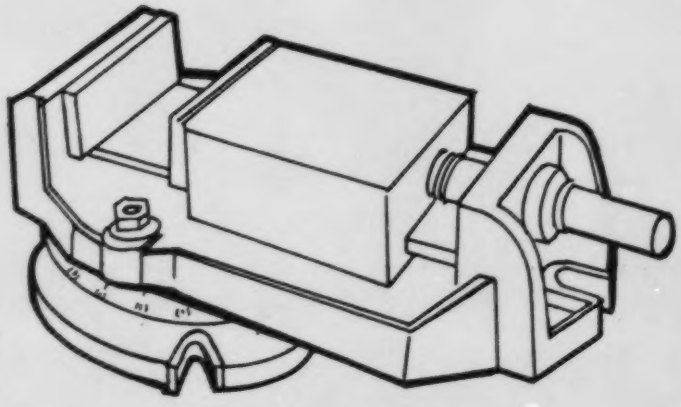
PLAIN VISE





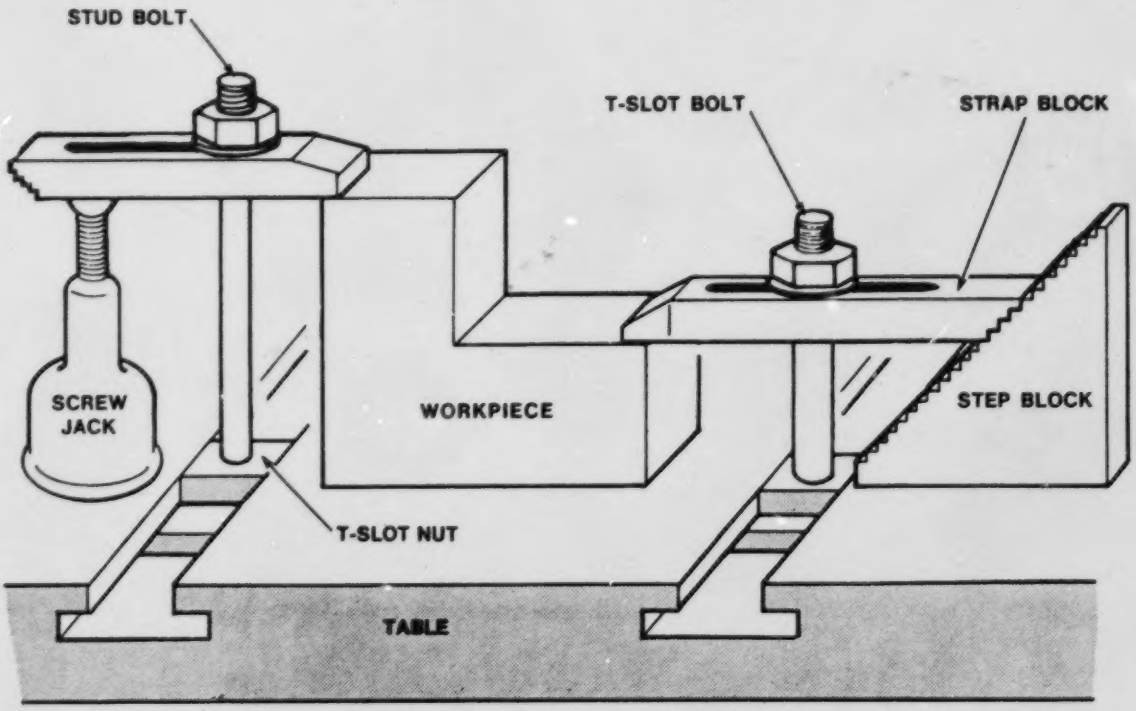
UNIVERSAL VISE

SWIVEL VISE

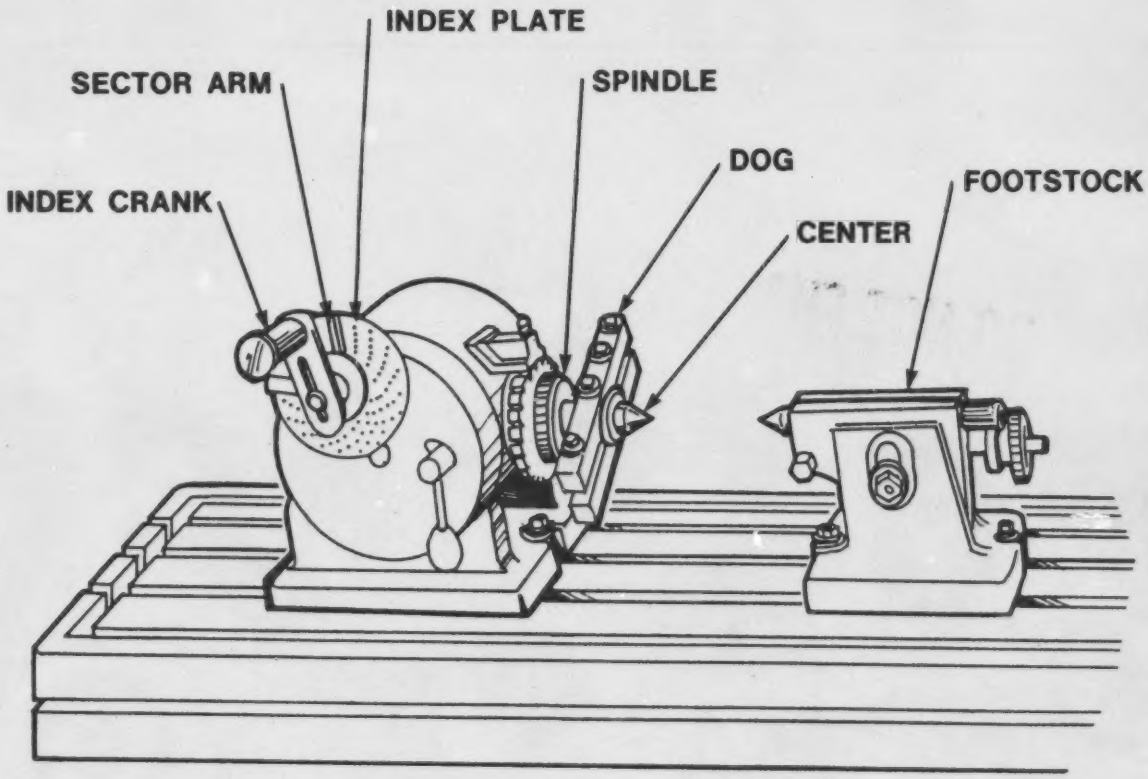


TM-4

# A TYPICAL SCREW JACK, CLAMP, AND BLOCK SET-UP



# PARTS OF A DIVIDING HEAD



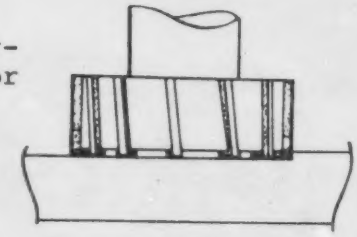

TM-6

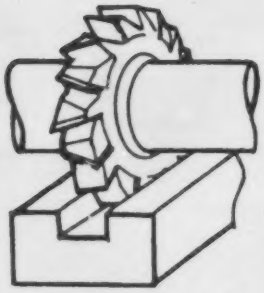
MILLING MACHINE OPERATOR

INFORMATION SHEET 5--OPERATION OF THE MILLING MACHINE

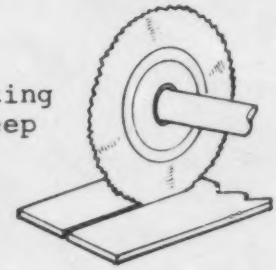
I. Types of operations

A. Facing--machining a flat surface with a shell end mill or end mill cutter

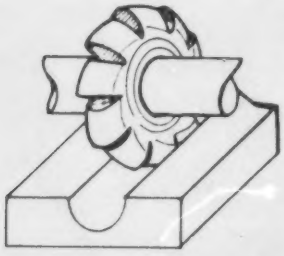




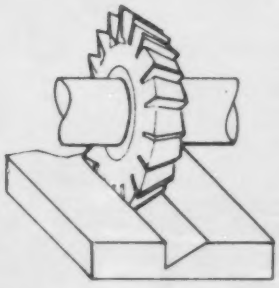
B. Groove or keyway cutting--cutting a slot in a flat or round workpiece with a plain mill or end mill cutter.



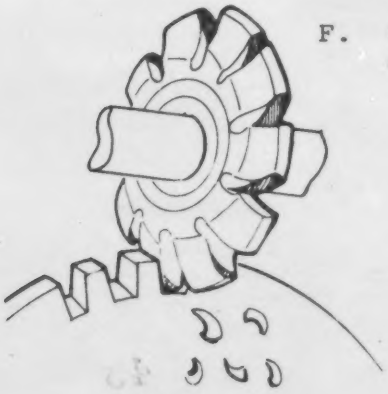
C. Slitting or cutoff--cutting a workpiece into or a deep slot in a workpiece.



D. Form cutting--cutting a radius, conves, or concave surface.

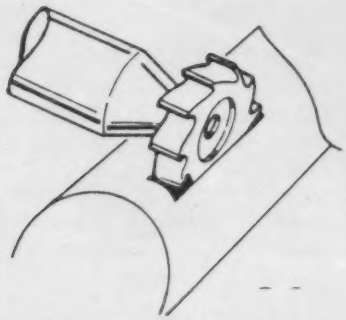


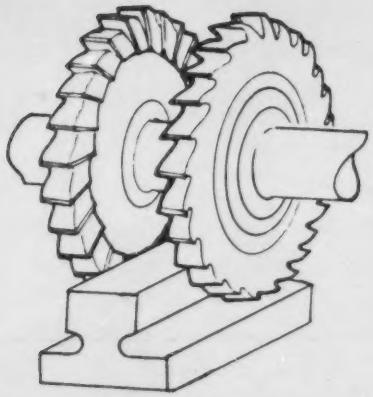
E. Angle cutting--cutting a single or double angle on a surface.



F. Gear cutting--cutting gear teeth on a workpiece or casting.

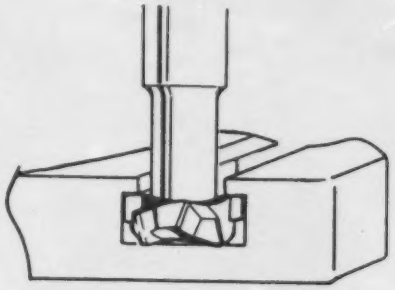
G. Straddle milling--cutting two sides of a workpiece with one pass, using side mill cutters.

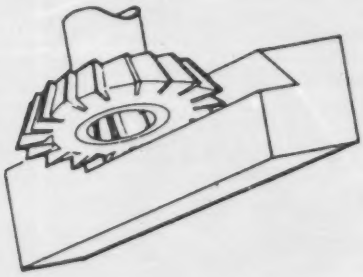




H. Woodruff keyseat cutting--cutting a slot for a half-moon key.

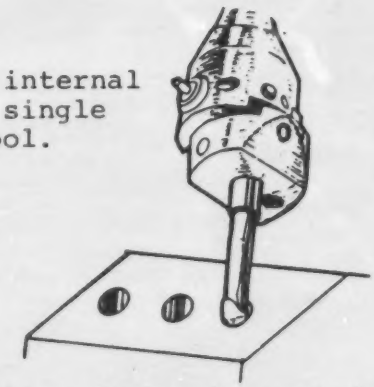
I. T-slot cutting--cutting a T-shaped groove for T-slot bolts and other hold down fixtures.





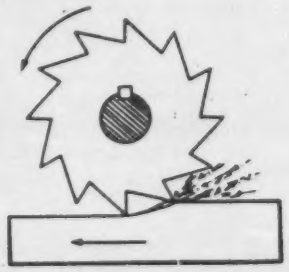
J. Dovetail cutting--cutting an internal V-shaped groove which is used for slides on machine tools.

K. Boring--cutting internal surfaces with a single point cutting tool.



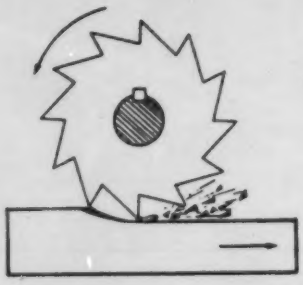
II. Methods of milling

A. Conventional milling (UP)--the workpiece is moving into the rotation of the cutter.



(NOTE: This is the safest and most commonly used method. Notice that the chip size increases during the cut.)

B. Climb milling (DOWN)--the workpiece and cutter are moving in the same direction.



(NOTE: This method can only be used on new machines or those designed for climb milling. Notice that the chip size decreases during the cut.)

III. Things to consider when setting feeds and speeds.

A. Type of metal being machined.

EXAMPLES: Mild steel, brass, aluminum, tool steel

(NOTE: This will be used to select the cutting speed and figure RPM.)

B. Hardness of metal being machined.

C. Type of cutting tool being used.

EXAMPLES: High speed steel, carbon steel, carbide

D. Type of cutter being used.

(NOTE: Cutters will vary by diameter, number of teeth, and cutting angle.)

E. Amount of material being removed.

1. Roughing cuts

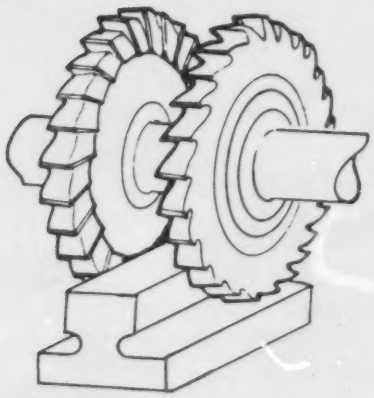
2. Finishing cuts

F. If a coolant is being used.

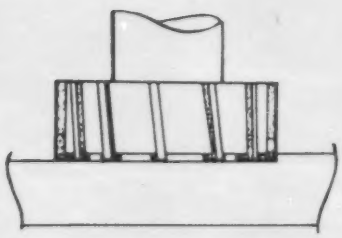
ASSIGNMENT SHEET 6--OPERATION OF THE MILLING MACHINE

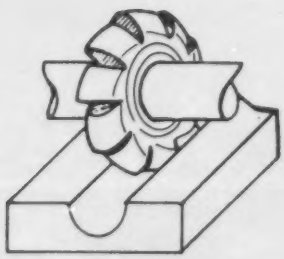
A. Identify the types of operations performed on the milling machine by writing the correct name below each illustration. Select from the list below.

Slitting
Keyway cutting
Angle cutting
Straddle milling
Dovetail cutting
Boring
Facing
Form cutting
Gear cutting
Woodruff keyseat cutting
T-slot cutting



1. _____ 2. _____





3. _____ 4. _____



ASSIGNMENT

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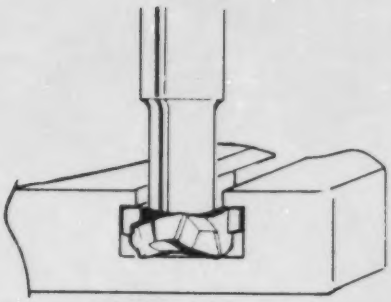
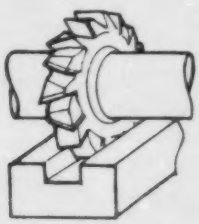
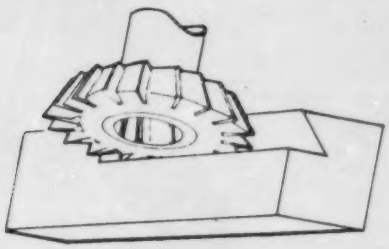
5. _____



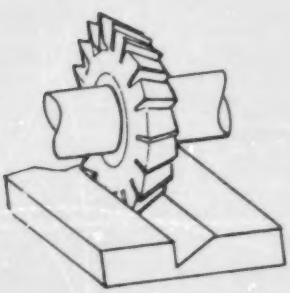
6. _____



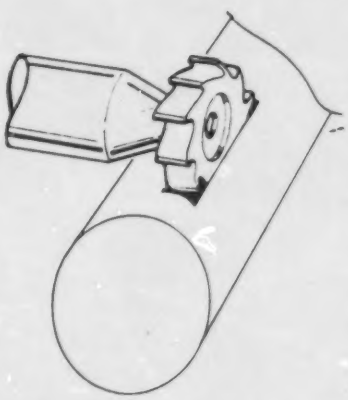
7. _____



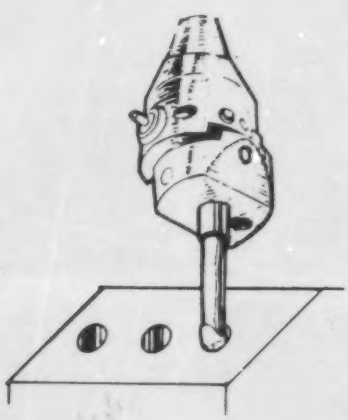
8. _____



9. _____

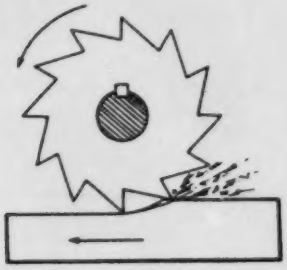


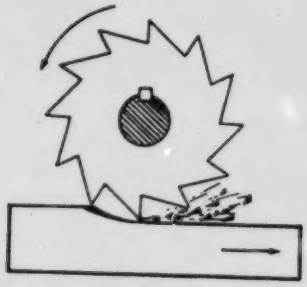
10. _____



11. _____

B. Identify the methods of milling by writing the name of each in the blank provided.





1. _____ 2. _____

C. Identify the things to consider when setting feeds and speeds on the milling machine by placing a "X" in front of each listed below.

____1. Type of metal being machined.

____2. Length of workpiece.

____3. Hardness of metal.

____4. Type of cutting tool being used.

____5. Type of vise holding workpiece.

____6. Type of cutter being used.

____7. Amount of metal being removed.

____8. If a coolant is being used.

ASSIGNMENT

## INFORMATION SHEET 6--MILLING CALCULATIONS

I. Cutting Speeds (CS)

A. Cutting speed refers to the distance, measured in feet, a point (tooth) on the cutter's circumference moves in one minute. This is expressed in terms of surface feet per minute (SFPM).

1. Factors to consider when determining and setting cutting speed

a. Reduce speeds for hard materials, abrasive materials, high alloy materials, and deep cuts.

b. Increase speeds for soft materials, better finishes, light cuts, and frail workpieces and setups.

c. Cutter type and material the cutter is made of.

d. Diameter of cutter (D).

e. Revolutions per minute (RPM).

f. Depth of cut.

(NOTE: Careful attention should be paid to all these factors to prevent dulling, burning, or breaking the cutter.)

2. Simplified formula: $CS = \frac{D \times RPM}{4}$

a. D = diameter of cutter.

b. RPM = revolutions per minute.

EXAMPLE: Using TM-7, RPM for high speed steel cutters, determine the CS for a 1-inch diameter cutter turning at 153 RPM's.

$$CS = \frac{D \times RPM}{4}$$

$$CS = \frac{1 \times 153}{4} = 38^{*} \text{ (ANSWER)}$$

3. Chart information - CS can be determined by simply reading it directly from the chart on TM-7.

(NOTE: $CS = \frac{\pi D \times RPM}{12}$ is another formula that may be used to determine cutting speed if greater accuracy is desired.)

II. Revolutions Per Minute (RPM)

A. Revolutions per minute is important for the speed setting of the spindle. When set correctly, the cutter turns at the proper cutting speed which increases the life of the cutter.

1. Factors to consider when determining and setting revolutions per minute.

a. Type of material being machined.

b. Cutter type and material the cutter is made of.

c. Type of cut, rough or finish.

2. Simplified formula: $RPM = \frac{4 \times CS}{D}$

a. CS = expressed on surface feet per minute (SFPM) on charts such as the one on TM-8.

b. D = diameter of cutter.

EXAMPLE: Using TM-8, figure the RPM's to set when finish cutting aluminum with a 4-inch diameter cutter made of high speed steel.

$$RPM = \frac{4 \times CS}{D}$$

$$RPM = \frac{4 \times 700}{4} = 700^{*} \text{ (ANSWER)}$$

(NOTE: $RPM = \frac{SFPM \times 12}{\pi D}$ is another formula that may be used to determine revolutions per minute if greater accuracy is desired.)

III. Feed (FTR)

A. Feed is the rate work moves into the cutter and is given as FEED PER TOOTH PER REVOLUTION. Feed should be as coarse as possible, consistent with the desired finish. The selection of the correct feed is one of the most difficult things that a machinist must determine.

1. Factors to consider when determining feed settings.

a. Width of cut.

b. Depth of cut.

c. Desired finish.

d. Condition of machine and cutter.

e. Type of material being machined.

f. Cutter type and material the cutter is made of.

2. Formula: F = FTR x T x RPM

a. FTR = feed per tooth per revolutions.

b. T = number of teeth in cutter.

c. RPM = revolutions per minute.

EXAMPLE: Using TM-6, determing the feed setting on the milling machine using an end mill with 4 teeth. Use the maximum FTR for free cutting steel and turn the cutter at 700 RPM's.

F = FTR x T x RPM

F = .010 x 4 x 700 = 28* (ANSWER)

# RECOMENDED FEED IN INCHES PER TOOTH

## High Speed Steel Cutters

| TYPE OF CUTTER | MATERIAL | | | | |
|---|---|---|---|---|---|
| | ALUMINUM | BRASS | CAST IRON | FREE CUTTING STEEL | ALLOY STEEL |
| End Mill | 0.009<br>0.022 | 0.007<br>0.015 | 0.004<br>0.009 | 0.005<br>0.010 | 0.003<br>0.007 |
| Face Mill | 0.016<br>0.040 | 0.012<br>0.030 | 0.007<br>0.018 | 0.008<br>0.020 | 0.005<br>0.012 |
| Shell End Mill | 0.012<br>0.030 | 0.010<br>0.022 | 0.005<br>0.013 | 0.007<br>0.015 | 0.004<br>0.009 |
| Slab Mill | 0.008<br>0.017 | 0.006<br>0.012 | 0.003<br>0.007 | 0.004<br>0.008 | 0.001<br>0.004 |
| Side Cutter | 0.010<br>0.020 | 0.008<br>0.016 | 0.004<br>0.010 | 0.005<br>0.011 | 0.003<br>0.007 |
| Saw | 0.006<br>0.010 | 0.004<br>0.007 | 0.001<br>0.003 | 0.003<br>0.005 | 0.001<br>0.003 |
| Form Cutter | 0.006<br>0.010 | 0.005<br>0.009 | 0.004<br>0.007 | 0.004<br>0.006 | 0.003<br>0.005 |

Increase or decrease feed until desired surface finish is obtained.

Feeds may be increased 100% or more, depending upon the rigidity of the machine and the power available, if carbide cutters are used.

(Source: MODERN METAL WORKING, pg. 38-16, Goodheart-Wilcox)

TM-7

# RPM FOR HIGH SPEED STEEL CUTTERS

| DIAMETER OF CUTTER (in inches) | CUTTING SPEEDS IN FEET PER MINUTE | | | | | | |
|---|---|---|---|---|---|---|---|
| | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| | Revolutions per Minute | | | | | | |
| 1/4 | 611 | 764 | 917 | 1,070 | 1,222 | 1,375 | 1,528 |
| 5/16 | 489 | 611 | 733 | 856 | 978 | 1,100 | 1,222 |
| 3/8 | 407 | 509 | 611 | 713 | 815 | 917 | 1,019 |
| 7/16 | 349 | 437 | 524 | 611 | 698 | 786 | 873 |
| 1/2 | 306 | 382 | 458 | 535 | 611 | 688 | 764 |
| 5/8 | 244 | 306 | 367 | 428 | 489 | 550 | 611 |
| 3/4 | 204 | 255 | 306 | 357 | 407 | 458 | 509 |
| 7/8 | 175 | 218 | 262 | 306 | 349 | 393 | 437 |
| 1 | 153 | 191 | 229 | 267 | 306 | 344 | 382 |
| 1 1/8 | 136 | 170 | 204 | 238 | 272 | 306 | 340 |
| 1 1/4 | 122 | 153 | 183 | 214 | 244 | 275 | 306 |
| 1 3/8 | 111 | 139 | 167 | 194 | 222 | 250 | 278 |
| 1 1/2 | 102 | 127 | 153 | 178 | 204 | 229 | 255 |
| 1 5/8 | 94 | 117 | 141 | 165 | 188 | 212 | 235 |
| 1 3/4 | 87 | 109 | 131 | 153 | 175 | 196 | 218 |
| 1 7/8 | 81 | 102 | 122 | 143 | 163 | 183 | 204 |
| 2 | 76 | 95 | 115 | 134 | 153 | 172 | 191 |
| 2 1/4 | 68 | 85 | 102 | 119 | 136 | 153 | 170 |
| 2 1/2 | 61 | 76 | 92 | 107 | 122 | 137 | 152 |
| 2 3/4 | 56 | 69 | 83 | 97 | 111 | 125 | 139 |
| 3 | 51 | 64 | 76 | 89 | 102 | 115 | 127 |
| 3 1/2 | 44 | 55 | 65 | 76 | 87 | 98 | 108 |
| 4 | 38 | 48 | 57 | 67 | 76 | 86 | 95 |
| 4 1/2 | 34 | 42 | 51 | 59 | 68 | 77 | 85 |
| 5 | 31 | 38 | 46 | 54 | 61 | 69 | 76 |
| 5 1/2 | 28 | 35 | 42 | 49 | 56 | 63 | 70 |

(Source: AMERICAN MACHINIST)

TM-8

# CUTTING SPEEDS

**In Surface Feet Per Minute (SFPM)**

| *MATERIAL* | *CUTTER TYPE* | | | |
|---|---|---|---|---|
| | High-Speed Steel | | Carbide-Tipped | |
| | Rough | Finish | Rough | Finish |
| Cast iron..... | 50-60 | 80-110 | 180-200 | 350-400 |
| Semisteel..... | 40-50 | 65-90 | 140-160 | 250-300 |
| Malleable iron. | 80-100 | 100-130 | 250-300 | 400-500 |
| Cast steel..... | 45-60 | 70-90 | 150-180 | 200-250 |
| Copper..... | 100-150 | 150-200 | 600 | 1,000 |
| Brass..... | 200-300 | 200-300 | 600-1,000 | 600-1,000 |
| Bronze..... | 100-150 | 150-180 | 600 | 1,000 |
| Aluminum..... | 400 | 700 | 800 | 1,000 |
| Magnesium..... | 600-800 | 1,000-1,500 | 1,000-1,500 | 1,000-5,000 |
| SAE steels | | | | |
| 1020 (coarse feed)..... | 60-80 | 60-80 | 300 | 300 |
| 1020 (fine feed) | 100-120 | 100-120 | 450 | 450 |
| 1035..... | 75-90 | 90-120 | 250 | 250 |
| 1050..... | 60-80 | 100 | 200 | 200 |
| 2315..... | 90-110 | 90-110 | 300 | 300 |
| 3150..... | 50-60 | 70-90 | 200 | 200 |
| 4340..... | 40-50 | 60-70 | 200 | 200 |
| Stainless steel | 100-120 | 100-120 | 240-300 | 240-300 |

Start at mid-point on the range and increase or decrease speed until best results are obtained.

(Source: AMERICAN MACHINIST)

## ASSIGNMENT SHEET 7--CUTTING SPEEDS

A. Define the term cutting speed.

B. List four factors to consider when determining and setting cutting speed.

1. _____

2. _____

3. _____

4. _____

C. Using TM-9, record the (SFPM) cutting speed for the various materials listed below. A high-speed steel cutter will be used for making a rough cut on all the materials.

____1. Cast iron

____2. Stainless steel

____3. Aluminum

____4. Brass

____5. 1035 carbon steel

____6. Bronze

D. Using the formula $CS = \frac{D \times RPM}{4}$ figure the cutting speed for a 2-inch diameter cutter turning at 95 RPM's.

ASSIGNMENT

## ASSIGNMENT SHEET 8--REVOLUTIONS PER MINUTE

A. Explain the importance of revolutions per minute.

B. List the factors to consider when determining and setting revolutions per minute.

1. _____

2. _____

3. _____

C. Using TM-8, write the RPM settings for high speed steel cutters for the size listed below operating at 60 SFPM.

____1. 3/4"

____2. 1 1/2"

____3. 3"

____4. 2"

____5. 5"

____6. 2 1/2"

D. Using the formula RPM = $\frac{4 \times CS}{D}$ figure the RPMs to set when rough cutting bronze with a 2-inch diameter carbide tipped cutter.

ASSIGNMENT

ASSIGNMENT SHEET 9--FEED SETTINGS

A. Define the term feed.

B. List four factors to consider when determining feed settings.

1. _____

2. _____

3. _____

4. _____

C. Using TM-7, write the feet in inches per tooth information for the cutter and material below. Record the maximum FTR for each.

____1. End mill, brass

____2. Face mill, alloy steel

____3. Shell end mill, aluminum

____4. Saw, cast iron

____5. Form cutter, free cutting steel

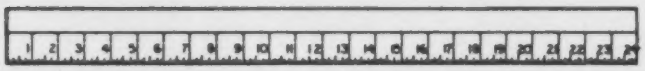
____6. Slab mill, aluminum

D. Using the formula F = FTR x T x RPM determine the feed setting for the milling machine using a face mill with 8 teeth. Use the minimum FTR for aluminum and turn the cutter at 1000 RPMs.

ASSIGNMENT

INFORMATION SHEET 7--BASIC HAND AND POWER TOOLS

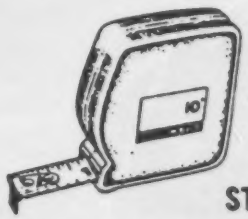
I. Hand Tools



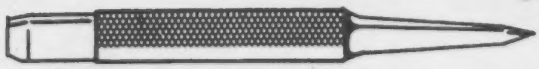
24" RULE

A. Steel rule or bench rule--used to lay off short measurements or to make straight lines. This rule is usually 24" long and is used for bench work only, since it cannot be carried in the pocket.

B. Steel pocket tape--available in different lengths, the steel blade is rigid enough for measuring straight surfaces, but it is also flexible enough for measuring curved or irregular surfaces.



STEEL TAPE



PRICK PUNCH

C. Prick punch--used first to mark the point where the centerlines intersect because of its sharp point.

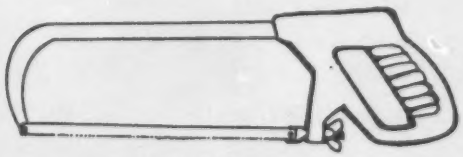
D. Center punch--used after the prick punch mark has been checked and found on center to enlarge the mark for drilling holes in metal.

CENTER PUNCH

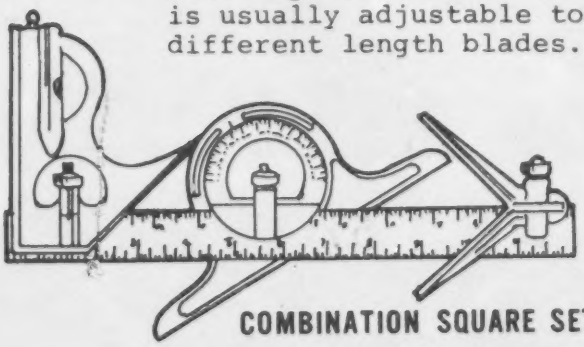
FILE

E. File--used to remove considerable metal, produce a smooth surface for layout work and produce keen edges on tools. CAUTION: Never use a file without a handle. It is too easy to drive the unprotected tang into your hand.

F. Hacksaw--used for cutting metal by hand. The frame is usually adjustable to different length blades.



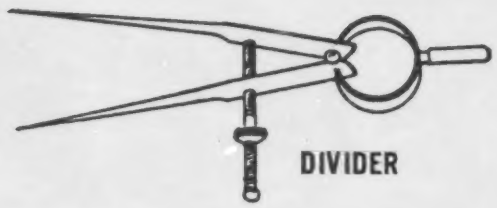
HACKSAW



COMBINATION SQUARE SET

G. Combination square set--adaptable to a large variety of operations in the shop. The complete combination set consists of a hardened blade, square head, center head and a bevel protractor.

H. Divider--used for laying out circles, parts of circles and for stepping off equal measurements. It is essential that both legs of the tool be equal in length and kept pointed.

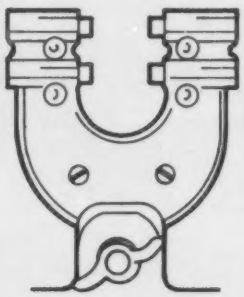


DIVIDER

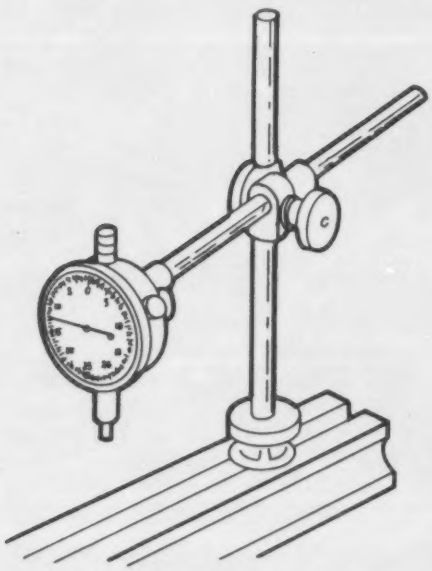
SCRIBE

I. Scribe--used to scribe or to scratch fine lines in a metal layout when accuracy is very critical. The point is made of hardened steel and kept needle sharp by frequent honing on a fine oilstone. CAUTION: Never carry an open scriber in your pocket.

J. Go and no-go gage--often called limits gages. Sometimes they are called double gages because they have two gaging points or surfaces. One tests the upper size limit and the other tests the lower size limit of a part being gaged. The sizes generally are stamped on the gage. Common types of go and no-go gages include snap gages, ring gages, and plug gages.



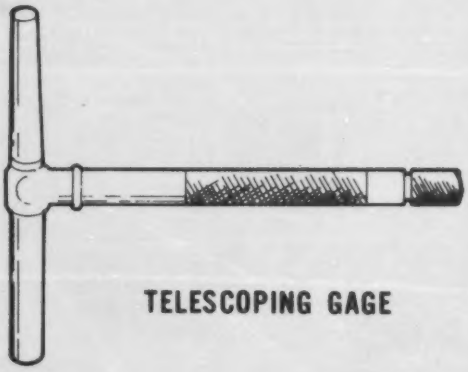
GO and NO GO GAGE



DIAL INDICATOR

K. Dial indicator--also called a dial gage and looks somewhat like a watch. The dial indicator shows visually the amount or error, in size or alignment, for a part being measured or gaged. It may be used for gaging height, gaging thickness and checking straightness or alignment of machined parts. The graduations on the dial indicator are generally indicated in thousandths (0.001), in ten-thousandths (0.0001) and in hundred-thousandths (0.00001).

L. Telescoping gage--used with the micrometer to determine inside measurements such as holes and grooves. To use the gage, compress the contact points which telescope within one another under spring tension, insert it into the hole or groove and permit the contents to expand. After the proper fitting is obtained, lock the contacts into position by tightening the knurled nut on the end of the handle. Remove the gage and measure the distance across the ends with a micrometer.



TELESCOPING GAGE

M. Small hole gage--permits measuring openings smaller than is possible with telescoping gages. The contacts are designed to permit accurate measurement of shallow grooves and are adjusted to size by the knurled knob at the end of the handle. Measurement is made over the contacts with a micrometer.

SMALL HOLE GAGE

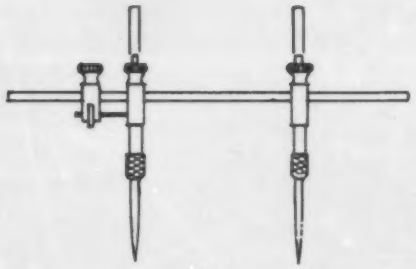
N. Hermaphrodite caliper--a layout tool which has one leg shaped like a caliper and the other pointed like a divider. The tool is used to layout lines parallel to the edge of the material and to locate the center of irregular and round shaped stock.

HERMAPHRODITE CALIPER

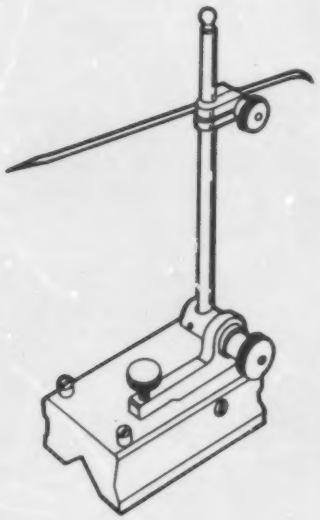
O. Vernier caliper--is used to make both inside and outside measurements. The vernier caliper can make accurate measurement to 1/1000 (0.001) inch.

VERNIER CALIPER

P. Trammel--used to scribe arcs or circles too large for ordinary dividers. It may also be used for locating different dimensions in a straight line. Moveover, it can be used as either inside or outside calipers, simply by removing the standard trammel points and inserting curved caliper legs in their place.



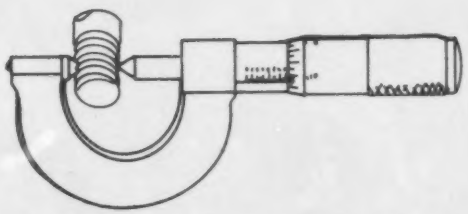
TRAMMEL



SURFACE GAGE

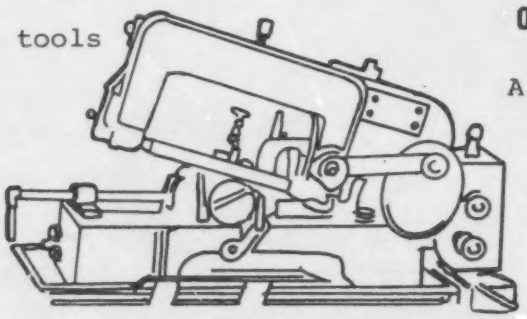
Q. Surface gage--used for many purposes but is most frequently used for layout work. The surface gage can be used for scribing lines, at a given height and parallel to a flat surface. It can also be used to level castings in a machine, to line up cutting tools or workpieces, or for inspection and checking of machine spindles and workpieces when an indicator is attached to it.

R. Outside micrometer caliper--used to measure outside diameters and thicknesses of material, parts, etc. Generally reads to the nearest one-thousandths (1/1000 or 0.001).



OUTSIDE MICROMETER CALIPER

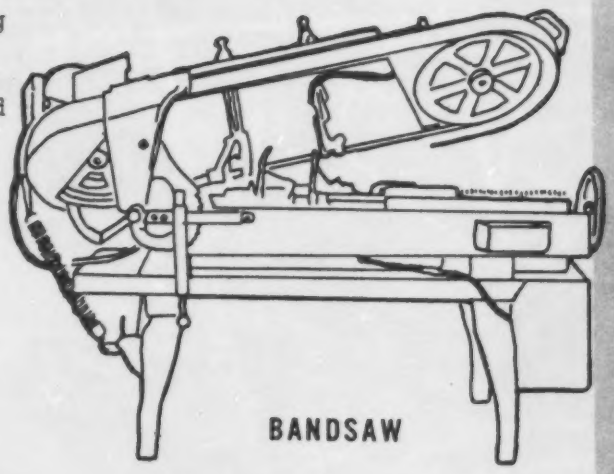
II. Power tools



POWER HACKSAW

A. Power hacksaw--used for cutting metal stock to length, using a recriprocating (back and forth, like a handsaw) movement.

B. Bandsaw--a machine having a continuous saw blade running on and driven by suitable pulleys and used for cutting stock to length.

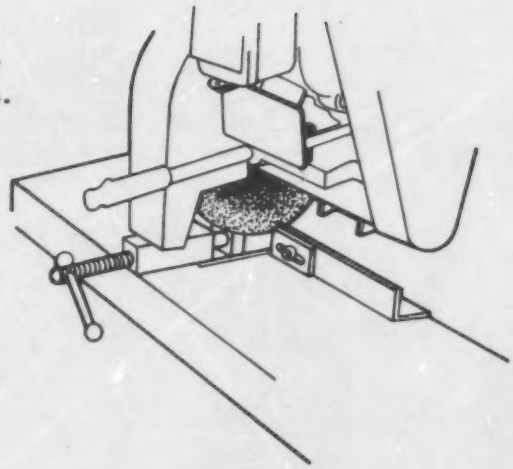


BANDSAW

DISK GRINDER

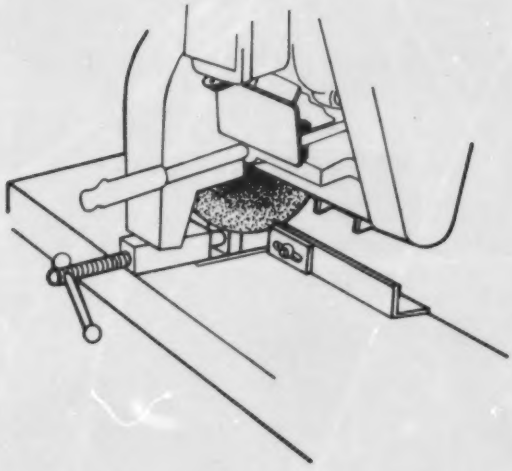
C. Portable disk grinder/sander--portable electric grinder commonly used in the shop for rough grinding. Uses 7- and 9-inch disk grinding wheels for grinding and wire cup brushes for removal of paint, rust, scale, and slag from welds.

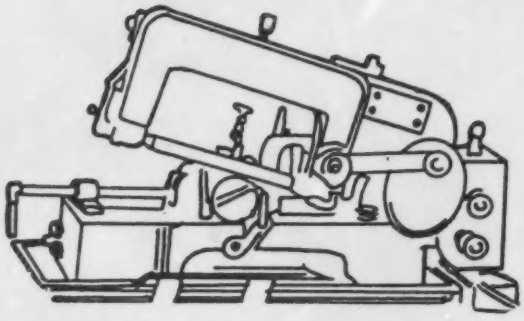
D. Abrasive Cutoff Saw--electrically powered saw similar to a circular saw, but cuts material by means of a rapidly revolving thin abrasive wheel to lengths. Typical sizes of cut-off disks are 10 and 14 inches in diameter and 1/8 inch in thickness.



B. Identify the power tools and write the names of each in the space provided.

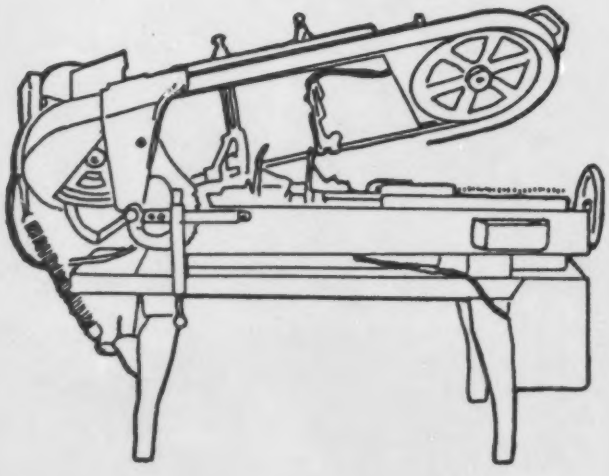
1. _____





2. _____

3. _____



4. _____

# MILLING MACHINE OPERATOR

## ASSIGNMENT SHEET 10--BASIC HAND AND POWER TOOLS

A. Match the correct word or words in the right-hand column to the definition in the left-hand column. Place the correct letter in the space provided on the left.

| | | |
|---|---|---|
| ____ 1. | Used for cutting metal by hand. | a. steel pocket tape |
| ____ 2. | Used to enlarge the prick mark for drilling holes. | b. divider |
| ____ 3. | Used to scribe or scratch fine lines in metal. | c. surface gage |
| ____ 4. | Consists of a hardened blade, square head, center head, and a bevel protractor. | d. prick punch |
| ____ 5. | Its blade is rigid enough for measuring straight surfaces, but flexible enough for measuring curved or irregular surfaces. | e. vernier caliper |
| ____ 6. | Used to measure outside diameters and thickness of material in 1/1000 (0.001) inch. | f. center punch |
| ____ 7. | This rule is usually 24" long and is used for bench work only. | g. combination square set |
| ____ 8. | Used for layout of circles. | h. small hole gage |
| ____ 9. | Used first to mark the point where the center lines intersect because of its sharp point. | i. telescoping gage |
| ____10. | Used to remove considerable metal, produce a smooth surface for layout work and produce keen edges on tools. | j. scribe |
| ____11. | Used to scribe lines at a given height and parallel to a flat surface. | k. trammel |
| ____12. | Used to locate centers on irregular and round shaped stock. | l. hacksaw |
| ____13. | Used to make both inside and outside measurements in 1/1000 (0.001) inch. | m. go and no-go gage |
| ____14. | Used to measure large holes and grooves. | n. hermaphrodite |
| ____15. | Used to scribe arcs or circles too large for dividers. | o. steel rule or bench rule |
| ____16. | Often called limit gages. | p. outside micrometer caliper |
| ____17. | Permits measuring openings smaller than is possible with telescoping gages. | q. file |

ASSIGNMENT

## INFORMATION SHEET 8--METALS AND SHAPES

I. History

Man has been dependent on metals since about 5000 B.C. Up to the Twentieth Century, man had only discovered about 12 different metals which included copper, gold, siver, lead, tin, iron, mercury, antimony, bismuth, magnesium, and aluminum. During the Twentieth Century, more metals have been produced than in all the history of the world. Of over 100 elements known to man, 80 to 90 of them are technically considered metals. The metals are generally identified as ferrous, nonferrous or an alloy.

To better understand the metals and their properties, industry has developed the science of metallurgy; and the individual who does this work is known as a metallurgist. One of the metallurgist's most important jobs is to develop metals with special properties that perform a specific job and do it as economically as possible.

II. Major groups of metals

A. Ferrous metals--metals containing mostly iron
   1. Cast iron
   2. Carbon steels

B. Nonferrous metals--metals containing no iron and are made up of single elements
   1. Aluminum
   2. Copper
   3. Lead
   4. Magnesium
   5. Nickel
   6. Tin
   7. Tungsten
   8. Zinc
   9. Silver
   10. Gold

C. Alloy metals--a mixture of two or more metals
   1. Ferrous alloy metals
      a. Aluminum steel
      b. Chrome steel

c. Manganese steel
d. Molybdenum steel
e. Nickel steel
f. Phosphorus steel
g. Silicon steel
h. Stainless steel
i. Tungsten steel
j. Vanadium steel

2. Nonferrous alloy metals
a. Brass
b. Bronze
c. Monel
d. Pewter
e. Solder

III. Metal shapes

Most rods, bars, sheets, plates, and structural shapes are produced by passing the metal through a series of forming rollers that gradually form the bloom or billet (semi-finished shapes of steel) of steel to the final shape and size.

A. Hot-rolled steel--rolled to desired shape and size while "red hot." Hot-rolled steel is identified by the bluish-black oxide that forms during and after the rolling process.

B. Cold-rolled steel--hot-rolled steel shapes that are pickled or treated by running them through a dilute acid to remove the oxide coating. The metal is then rolled cold to the finished shape and size. Cold-rolled steel can be identified by its bright, shiny, silvery, and oxide-free surface.

C. Shapes commonly used in milling.

1. Sheet--less than 1/4" thick.

2. Plate--more than 1/4" thick.

3. Strips--less than 1/4" thick, up to 12" wide.

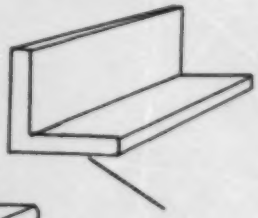
4. Flats--more than 1/4" thick, up to 6" wide.

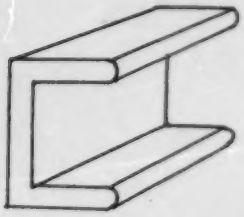
5. Round.

6. Square.

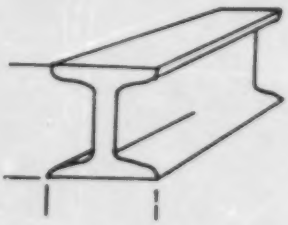
7. Hexagon--six sided.

8. Octagon--eight sided.

9. Angle--equal or unequal legs. 

10. Channel. 

11. I-beam--height and flange width unequal.

12. H-beam--height and flange width equal. 

ASSIGNMENT SHEET 11--METAL AND SHAPES

A. What is the most important job of a metallurgist?

B. List the three major groups of metals.

1. _____

2. _____

3. _____

C. Explain the meaning of each of the following two terms.

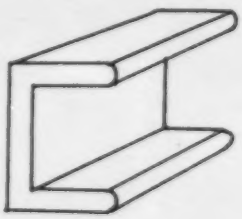
1. Hot-rolled steel--

2. Cold-rolled steel--

D. Identify the common shapes of metal and write the names of each in the blank provided.

| | | | |
|---|---|---|---|
| sheet | flats | hexagon | channel |
| plate | round | octagon | I-beam |
| strips | square | angle | H-beam |

1. _____



2. _____

3. _____

4. _____

ASSIGNMENT

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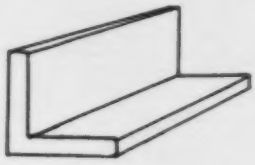
5. _____

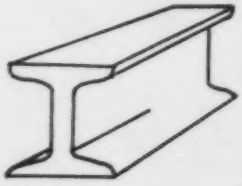
6. _____

7. _____



8. _____

9. _____



10. _____

11. _____

12. _____

# MILLING MACHINE OPERATOR

## TEST PART 1

Directions: Match the terms associated with milling operations to the correct definition by writing the number of each item on the right in the correct blank on the left.

____a. The centerline of the workpiece or stock.

____b. A shaft or spindle on the milling machine that holds mill cutters.

____c. The line or area that indicates a safe distance from a cutter or machine.

____d. Cutting a hole with a tool called a drill.

____e. Upright or at a right angle to the ground.

____f. Parallel to the ground or level.

____g. To remove metal with a rotating cutter on milling machine.

____h. The process of dividing round or other shaped workpieces into equal divisions or spaces using the dividing head.

____i. A liquid used to cool and lubricate the cutting tool.

____j. Material or item being shaped or cut during the milling process.

____k. Revolutions per minute.

____l. The rate the workpiece moves into the cutter and is expressed as FTR.

____m. Device for holding the workpiece during the milling process.

____n. Slot in a shaft to hold a key.

____o. Outside distance around the curved edges of a round part.

1. Vise
2. Axis
3. Circumference
4. Horizontal
5. Indexing
6. Safety zone
7. Drilling
8. Mill
9. Vertical
10. Workpiece
11. Arbor
12. Keyway
13. Feed
14. Cutting fluid
15. RPM

# MILLING MACHINE OPERATOR

## TEST PART 2

Directions: Point out the correct safety practices to follow when operating the milling machine by answering TRUE or FALSE to each of the following statements.

_____a. Safety glasses should be worn only when the machine is running.

_____b. Clean the table before mounting accessories.

_____c. Cutters can rotate either direction and still cut.

_____d. Cutters should be handled with shop rags.

_____e. The arbor nut should be tightened by using the power for the spindle.

_____f. Make all adjustments with the machine stopped.

_____g. It is better to use the same spindle speed and feed for machining all parts.

_____h. Use a ball-peen hammer to seat the workpiece in the vise.

_____i. Leave all handwheels engaged for quick adjustments during operations.

_____j. Use hand feed when bringing the workpiece up to the cutter.

# MILLING MACHINE OPERATOR

## TEST PART 3

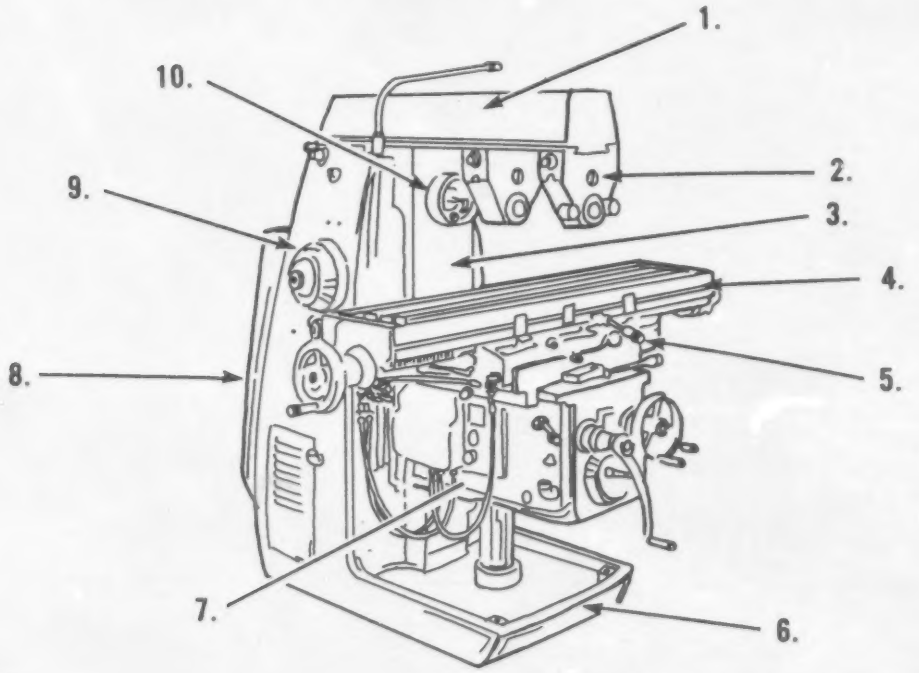
1. Identify the two classifications of milling machines.

   a. _____

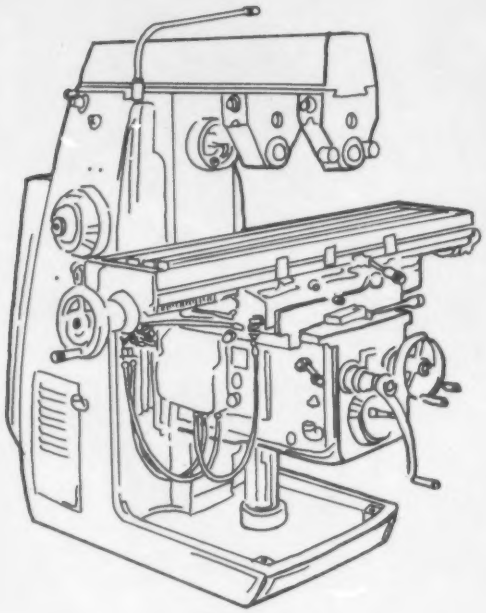
   b. _____

2. Identify the parts of a milling machine by labeling the illustration below with the correct name from the list.

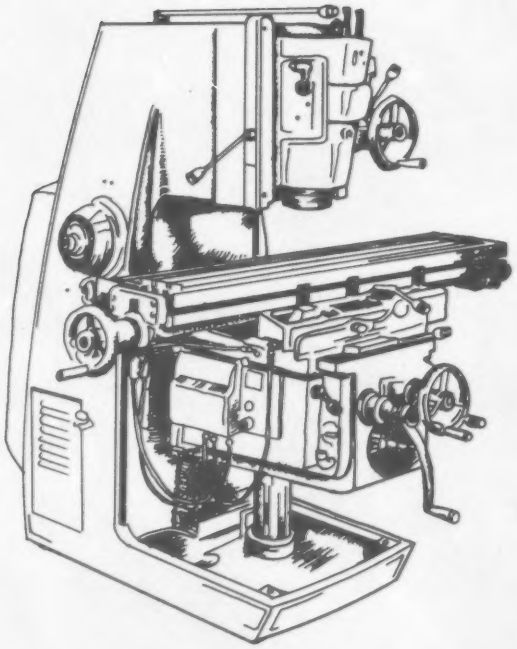
| | | |
|---|---|---|
| Column | Table | Arbor support |
| Base | Overarm | Motor assembly |
| Knee | Speed selector | |
| Saddle | Spindle | |



3. Identify which of the milling machines is horizontal or vertical type by writing the name of each in the space provided.



a. _____



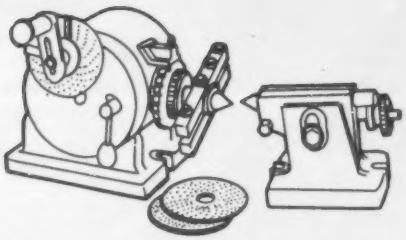
b. _____

# MILLING MACHINE OPERATOR

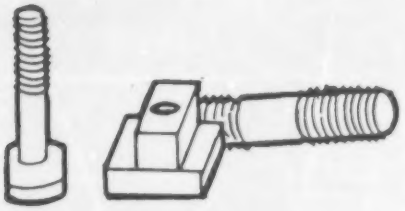
## TEST PART 4

1. Identify the work holding devices used on the milling machine by writing each of the following names next to the correct illustration.

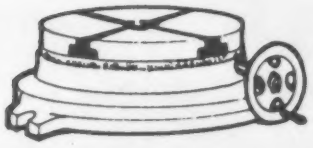
| | |
|---|---|
| Plain mill vise | Dividing head |
| T-slot bolt | Screw jack |
| T-slot clamp | Dividing head |
| Safety blocks | Rotary table |



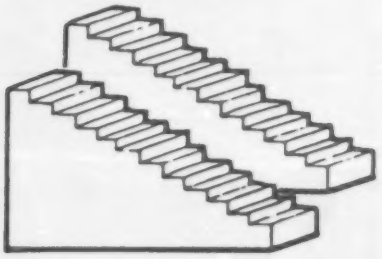
a. _____



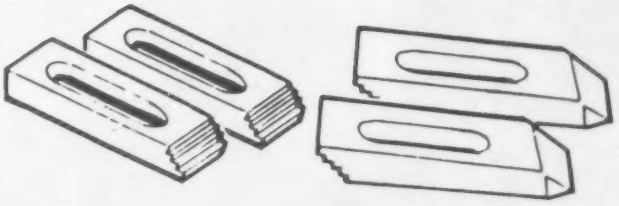
b. _____



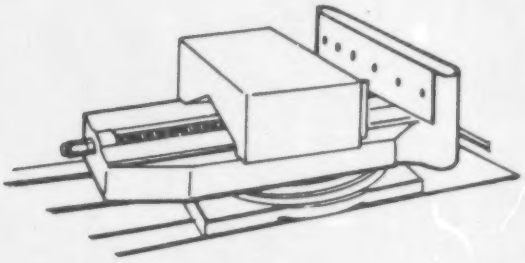
c. _____



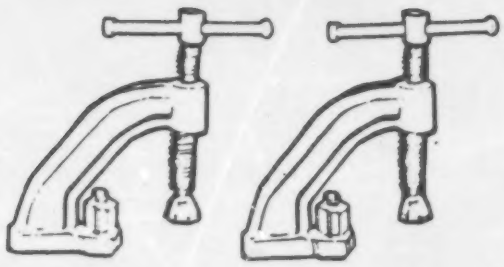
d. _____



e. _____



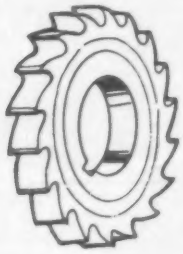
f. _____



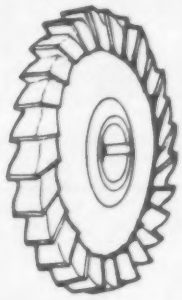
g. _____ h. _____

2. Identify the types of milling cutters used on the milling machine by writing each name in the list below in the correct blank.

| | |
|---|---|
| Face-mill cutter | Plain mill cutter |
| Key-seat cutter | Side mill cutter |
| T-slot mill cutter | Metal slitting saw |
| End-mill cutter | Angle mill cutter |
| Helical plain mill cutter | Formed tooth cutter |
| Flycutter | Boring bar |

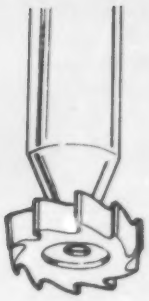


a. _____ b. _____

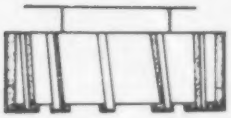


c. _____ d. _____

e. _____



f. _____

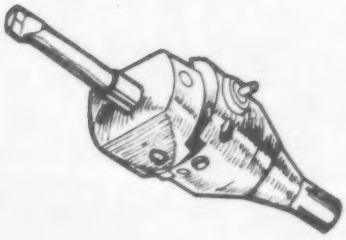


g. _____

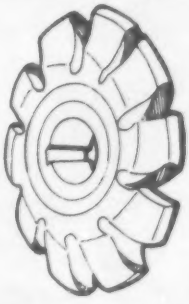
h. _____

i. _____

j. _____



k. _____



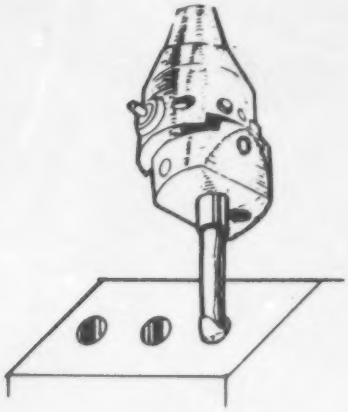
l. _____

# MILLING MACHINE OPERATOR

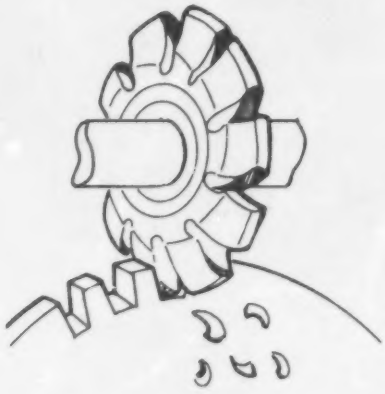
## TEST PART 5

1. Identify the types of operations performed on the milling machine by writing each of the names listed below in the space by the correct illustration.

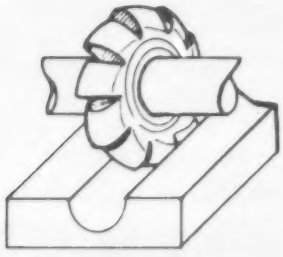
| | |
|---|---|
| Slitting | Facing |
| Keyway cutting | Form cutting |
| Angle cutting | Gear cutting |
| Dovetail cutting | Woodruff keyseat cutting |
| Boring | T-slot cutting |



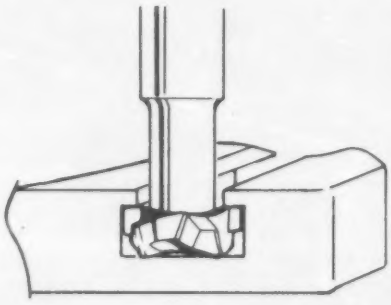
a. _____



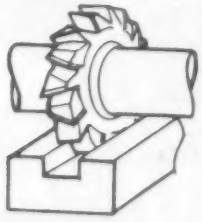
b. _____



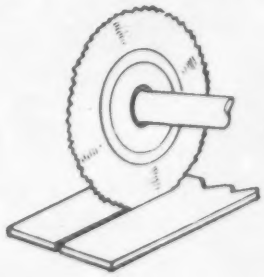
c. _____



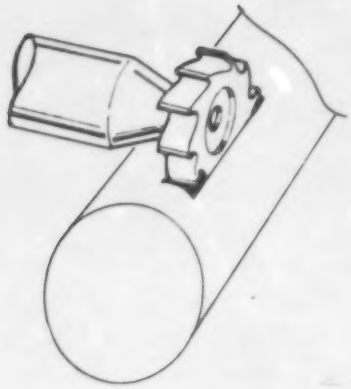
d. _____



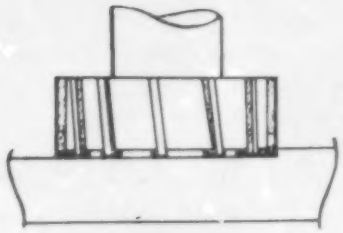
e. _____



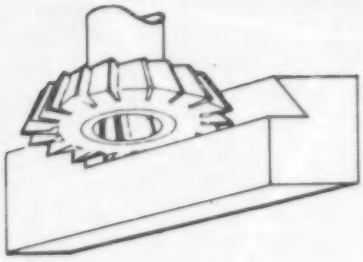
f. _____



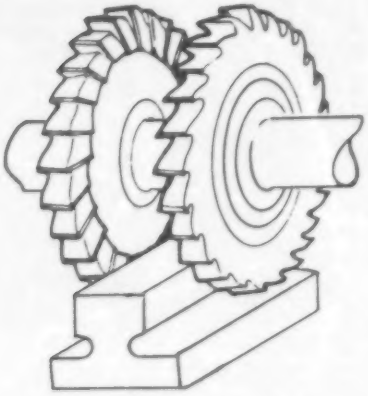
g. _____



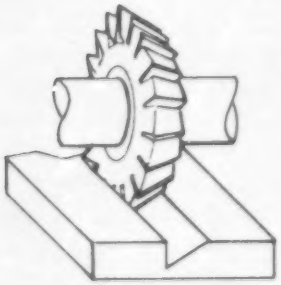
h. _____



i. _____

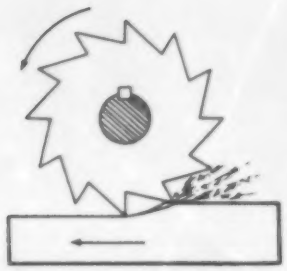


j. _____

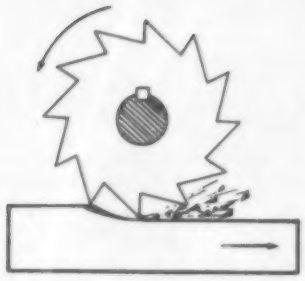


k. _____

2. Identify the methods of milling by writing the name of each in the blank provided.



a. _____



b. _____

3. Identify the things to consider when setting feeds and speeds on the milling machine by placing an "X" in front of each item listed below.

____a. Type of metal being machined.

____b. Length of workpiece.

____c. Hardness of metal.

____d. Type of cutting tool being used.

____e. Type of vise holding workpiece.

____f. Type of cutter being used.

____g. Amount of metal being removed.

____h. If a coolant is being used.

# MILLING MACHINE OPERATOR

## TEST PART 6

1. Define the following terms:

   a. Cutting speed--

   b. Feed--

2. Using the formula $CS = \frac{D \times RPM}{4}$ figure the cutting speed for a 3-inch diameter cutter turning at 40 RPM's.

3. Using the formula $RPM = \frac{4 \times CS}{D}$ figure the RPM's to set when rough cutting cast iron with a 1-inch diameter carbide tipped cutter if CS equals 100.

4. Using the formula F = FTR x T x RPM determine the feed setting for the milling machine using an end mill with 2 teeth. FTR's are 0.022 for aluminum and the RPM's are 500.

# MILLING MACHINE OPERATOR

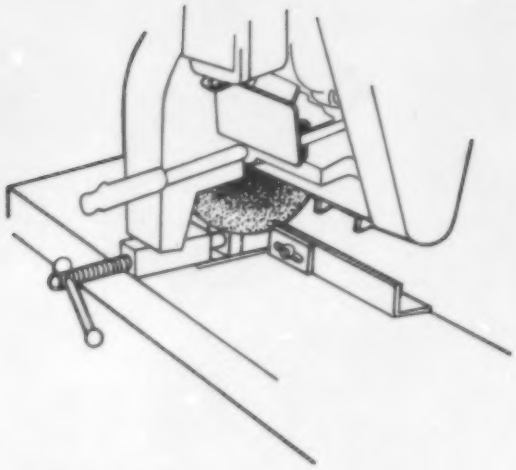
## TEST PART 7

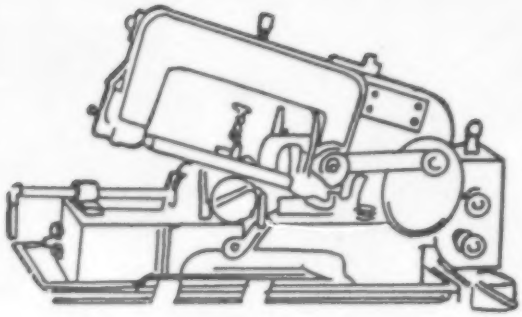
1. Match the correct word or words in the right-hand column to the definition in the left-hand column. Place the correct letter in the space provided on the left.

| | | | |
|---|---|---|---|
| ____a. | Used for cutting metal by hand. | 1. | steel pocket tape |
| ____b. | Used to enlarge the prick mark for drilling holes. | 2. | Divider |
| ____c. | Used to scribe or scratch fine lines in metal. | 3. | Surface gage |
| ____d. | Consists of a hardened blade, square head, center head, and a bevel protractor. | 4. | Prick punch |
| ____e. | Its blade is rigid enough for measuring straight surfaces, but flexible enough for measuring curved or irregular surfaces. | 5. | Vernier caliper |
| ____f. | Used to measure outside diameters and thickness of material in 1/1000 (0.001) inch. | 6. | Center punch |
| ____g. | This rule is usually 24" long and is used for bench work only. | 7. | Combination square set |
| ____h. | Used for layout of circles. | 8. | Small hole gage |
| ____i. | Used first to mark the point where the center lines intersect because of its sharp point. | 9. | Telescoping gage |
| ____j. | Used to remove considerable metal, produce a smooth surface for layout work, and produce keen edges on tools. | 10. | Scribe |
| ____k. | Used to scribe lines at a given height and parallel to a flat surface. | 11. | Trammel |
| ____l. | Used to locate centers on irregular and round shaped stock. | 12. | Hacksaw |
| ____m. | Used to make both inside and outside measurements in 1/1000 (0.001) inch. | 13. | Go and no-go gage |
| ____n. | Used to measure large holes and grooves. | 14. | Hermaphrodite caliper |
| ____o. | Used to scribe arcs or circles too large for dividers. | 15. | Steel rule or bench rule |
| ____p. | Often called limit gages. | 16. | Outside micrometer caliper |
| ____q. | Permits measuring openings smaller than is possible with telescoping gages. | 17. | File |

2. Identify the power tools and write the names of each in the space provided.

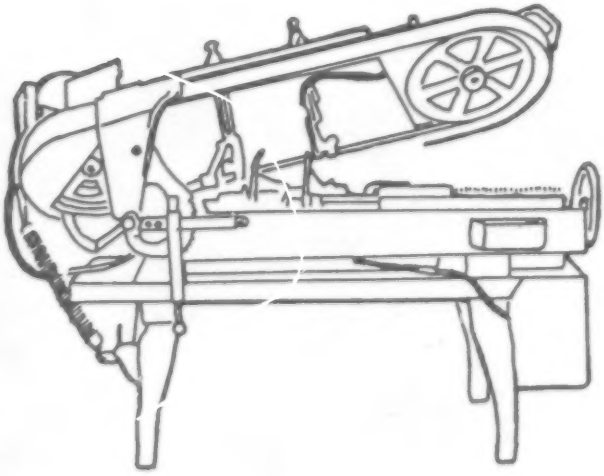
a. _____





b. _____

c. _____



d. _____

# MILLING MACHINE OPERATOR

## TEST PART 8

1. What is the name of the person who works with metals?

2. Below is a list of the common shapes of metal. Choose from the list and write the name of each shape in the space provided under each picture.

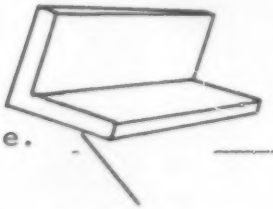
| | | | |
|---|---|---|---|
| sheet | flats | hexagon | channel |
| plate | round | octagon | I-beam |
| strips | square | angle | H-beam |

a. _____

b. _____

c. _____

d. _____

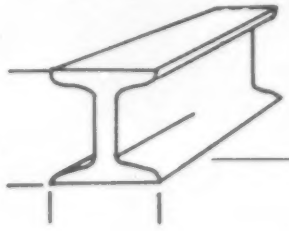
e.  _____

f. _____

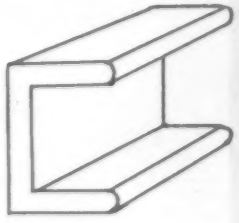
g. _____

h. _____

i. _____

j.  _____

k. _____

l. _____ 

3. Choosing from the list below, complete the sentences:

   alloy metals  nonferrous metals  ferrous metals

   a. Metals that contain a mixture of two or more metals are called _____.

   b. Metals that contain mostly iron are called _____.

   c. Metals that contain no iron and are made up of single elements are called _____.

4. Complete the following sentences by circling the correct answer.

   a. Hot-rolled steel is rolled out to the desired shape and size while it is (icy cold) (red hot).

   b. The color of hot-rolled steel is (bluish black) (reddish tan).

   c. Cold-rolled steel is made from (steel bars) (hot-rolled steel shapes).

   d. The color of cold-rolled steel is (bright, shiny, silver) (dull,dark, and bluish).